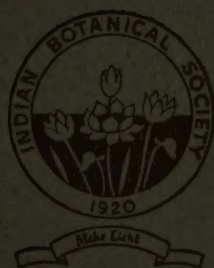


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EMBRYOLOGICAL STUDIES IN *LECYTHIDACEÆ*—I

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LECYTHIDACEÆ is a small family of Myrtifloræ. Bentham and Hooker (1862–83) include the genera of this family in Myrtaceæ itself, but Engler and Prantl (1892), Rendle (1925), Hutchinson (1926) and Wettstein (1935) recognise it as a distinct family, though closely allied to Myrtaceæ. The genera of this family are classified into four groups, namely, (1) *Fœtidioideæ*, (2) *Planchonioideæ*, (3) *Napoleonoideæ* and (4) *Lecythidoideæ*.

The embryology of this family is but little known and is limited to a few observations on the embryo of *Barringtonia vriesei* by Treub (1884) and on the structure and development of the ovule and embryo-sac of *Barringtonia acuminata*, *B. asiatica*, *B. speciosa*, *Gustavia augusta* and *Couroupita guianensis* by Mauritzon (1939). The ovules in these are tenuinucellate and two integumented. The inner integument alone forms the micropyle. The vascular bundle of the funicle travels up into the massive outer integument. The archesporial cell in the ovule directly forms the megaspore mother cell which undergoes the two meiotic divisions and forms a linear or T-shaped tetrad. The chalazal-most megaspore is the functional one and forms the embryo-sac according to the Normal type. Mauritzon did not see antipodals in his preparations, but he surmised that they degenerate early, if formed. Endosperm is nuclear in *Couroupita*, *Barringtonia racemosa* and *B. sumatrana*, but cell formation takes place in the chalazal part later on.

No details of structure and development of pollen and anther are available in the family and no representatives of *Napoleonoideæ* or *Fœtidioideæ* have been investigated so far.

The present paper deals with the structure and development of the anther and pollen, ovule and embryo-sac of *Napoleona imperialis* Pal B., a representative of *Napoleonoideæ* and also with the structure and development of pollen and anther in *Barringtonia acutangula* Gaertn. A few observations on the ovule of the latter species are also included in the present account.

MATERIAL AND METHODS

The materials of *Napoleona imperialis* and *Barringtonia acutangula* were fixed in formalin acetic alcohol and Nawaschin's fluid, the former from plants growing in the Indian Botanic Gardens, Sibpur, Howrah, and the latter from plants growing in Kakinada, S. India. Customary methods of dehydration and infiltration were followed. Sections of 10–14 μ thick were cut and stained in Iron-alum hæmatoxylin, Delafield's hæmatoxylin and Safranin and Fast Green, F.C.F.

DEVELOPMENT AND STRUCTURE OF THE ANTHER AND POLLEN

The stamens are many in both the plants. In *Barringtonia acutangula* all the stamens are fertile. Their filiform pink filaments are connate below and form a short staminal tube which is adnate to the petals. In *Napoleona imperialis* the stamens are found in many series, the outer being staminodal and petaloid.

The primary archesporium in the anther has been observed only in *Barringtonia acutangula*. It consists of a single row of six or seven hypodermal cells in each of the four lobes of the anther (Figs. 1 and 2). A periclinal division of this results in the formation of an outer parietal and an inner sporogenous layer (Fig. 3). As a result of periclinal divisions in the former, four wall layers are found under the epidermis, the outermost of which develops into the fibrous endothecium and the innermost into the tapetum (Figs. 4–6 and 15). The two middle layers get crushed in the mature anthers (Fig. 16).

At about the time of cytokinesis in the tetranucleate pollen mother cells, a substance is deposited on the inner side of the tapetal walls in the form of minute granules which give rise to small markings there. These are clear in both the species but are more prominent in *Napoleona imperialis* (Fig. 17). Such markings also appear on the inner side of the endothelial cells at the time when the middle layers of the wall get disorganized (Fig. 9). These are similar to those recorded in *Chenopodium album* (Bhargava, 1936), *Achyranthes aspera*, *Digera arvensis*, *Clematis Flammula*, *Galphimia gracilis*, *Lilium* sps., *Gisekia pharnaceoides*, *Bærhaavia diffusa*, *B. repanda* (Kajale, 1940), and in several other angiosperms (Ubisch, 1927; Kosmath, 1927) and seem to be of quite common occurrence in angiosperms.

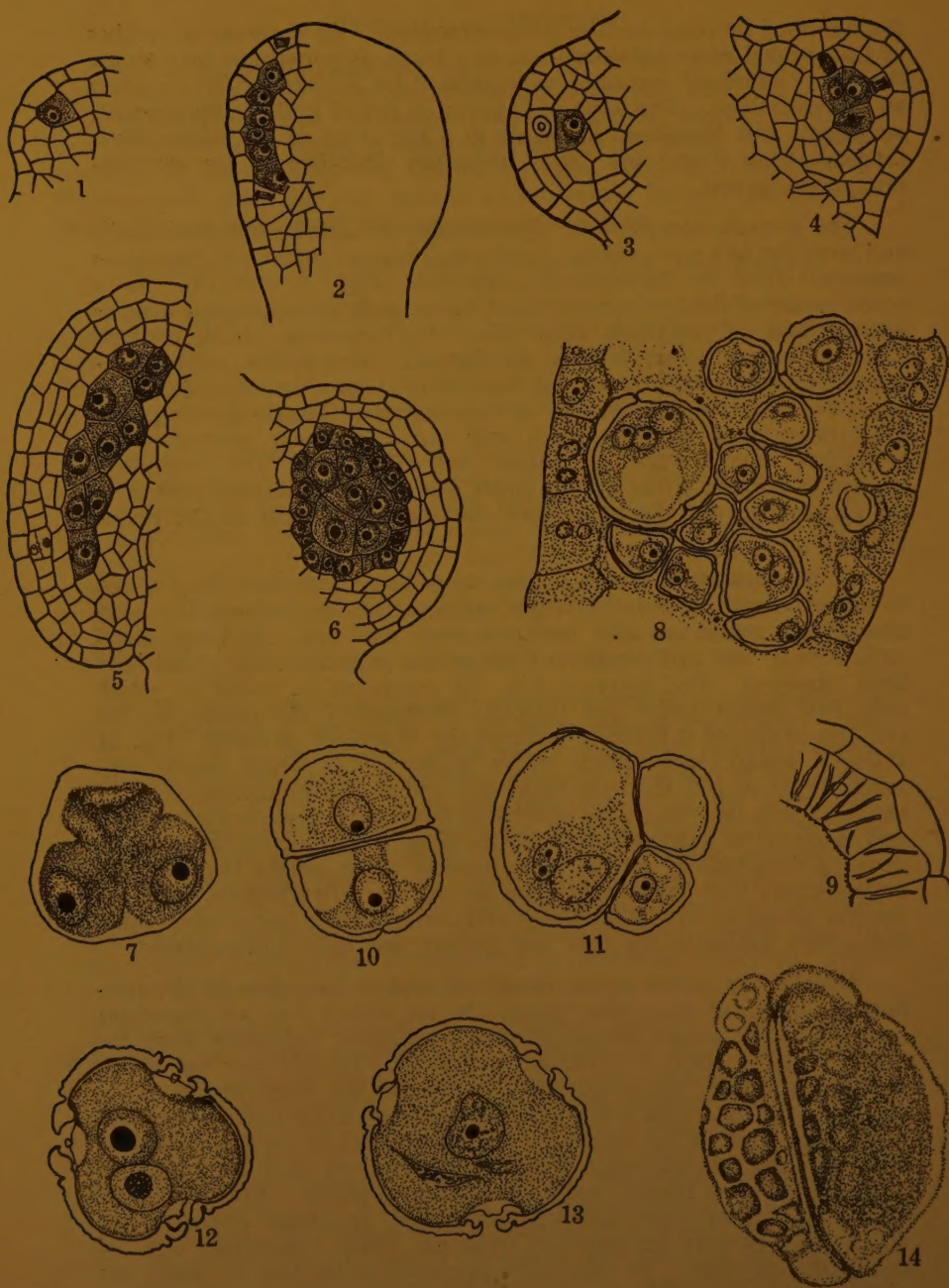
The tapetal cells become binucleate at about the time of the I meiotic division in the pollen mother cells. At about the time when pollen grains of the tetrad become free from each other, first the inner walls and then the radial walls of the tapetal cells disorganize and the cytoplasm from them flows out forming a periplasmodium. It spreads between the developing pollen grains, but the nuclei of the tapetal cells, which are in a degenerate stage by now, retain their original positions. In this feature it differs from the true periplasmodium (in the sense of Tischler, 1915) which is characterised by not only the complete fusion of the protoplasts into a syncytium but also by the presence of perfect and healthy nuclei floating in the periplasmodial mass (Tischler, 1915; Narasimhamurty, 1938; Sănè, 1939) and has been

distinguished by some as false periplasmodium. As there are a number of transitional cases between these two types, it is perhaps best to use the term 'amœboid tapetum' as suggested by Schnarf (1929) to cover all the variations. This type of tapetum is found both in *Barringtonia acutangula* and *Napoleona imperialis* at a late stage of the anther development (Figs. 8 and 16). It is ultimately absorbed by the developing pollen grains.

The primary sporogenous layer divides anticlinally and periclinally and gives rise to a sporogenous tissue which is more massive in *Napoleona imperialis* than in *Barringtonia acutangula* (Figs. 6 and 15). As a consequence of the two meiotic divisions the pollen mother cells become tetranucleate. Cytokinesis takes place by furrowing. Both bilateral and tetrahedral pollen tetrads are formed. The pollen grains of a tetrad remain together upto the binucleate stage (Fig. 18). In *Napoleona imperialis* the first division of the nucleus in the uninucleate pollen grain takes place near the outer wall and a lenticular generative cell is formed later towards the outer wall (Fig. 18). The vegetative nucleus is formed either on the inner side of the generative cell or in the corner between the outer wall and the radial walls of the pollen grain.

In *Barringtonia acutangula* also, the pollen grains have been found to remain together but the stages suitable for ascertaining the position of the generative cells have not been met with. In some cases, variations in size and number of the pollen grains in each tetrad have been observed. For instance Fig. 10 represents a tetrad in which only two pollen grains are formed. Presumably the pollen mother cell that produced it failed to undergo the II meiotic division. Fig. 11 shows a tetrad with three pollen grains out of which one is very much larger in size than the other two and is also binucleate. Out of the remaining two which are smaller in size, one is poor in its contents and seems to be degenerating while the other is only uninucleate. Fig. 8 shows a longitudinal section of a portion of an anther lobe showing pollen grains free from each other as well as a few tetrads. One of the free grains is very large in size and contains three nuclei while other free pollen grains in the lobe are smaller and only one-nucleate.

Usually the pollen grains round off and become free in the two-nucleate stage of the pollen grain. In an anther lobe of *Napoleona imperialis* some pollen tetrads showed a different behaviour from the usual. One of them is sketched in Fig. 23. In this case the pollen grains are already three-nucleate. In two of the three pollen grains visible in the figure the lenticular generative cell is formed towards the outer wall, while in the third it is not clearly seen to be organized into a distinct cell. In addition to the generative cell, each of the pollen grains shows two nuclei, one of them larger in size than the other. The same anther lobe also contains some abnormal pollen grains which have already become free from the tetrad condition. Fig. 24 shows one of them. In this there are four nuclei two of which are bigger than the remaining two. The smaller seem to be a pair of generative nuclei. Fig. 25 shows another case of a pollen grain with



Figs. 1-14

FIGS. 1-14. *Barringtonia acutangula*.—Figs. 1 and 2. Primary archesporium in T.S. and L.S. of an anther respectively, $\times 430$. Figs. 3, 4 and 6. T.S. of anther at different stages of development, $\times 430$. Fig. 5. L.S. of anther showing epidermis, two wall layers and sporogenous tissue, $\times 430$. Fig. 7. Tetranucleate pollen mother cell showing cytokinesis by furrowing, $\times 1,010$. Fig. 8. Part of L.S. of anther lobe showing pollen grains with variations in size and number of nuc'ei. Some are in the tetrad condition, $\times 430$. Fig. 9. L.S. of mature anther wall. Minute granular markings are seen on the inner walls of the endothecium, $\times 430$. Figs. 10 and 11. Abnormal pollen tetrads, one with only two and the other with only three pollen grains, $\times 685$. Figs. 12 and 13. Sections of 2- and 3-nucleate pollen grains, $\times 685$. Fig. 14. Side view of an entire pollen grain showing sculptured surface of the exine, $\times 1,420$.

super-numerary nuclei. It contains 5 nuclei two of which are smaller and enclosed within the generative cell, while the remaining three are free and bigger in size. The latter seem to be 3 vegetative nuclei and the two enclosed within the small lenticular cell to be generative nuclei. Such abnormal cases have been recorded previously in a number of angiosperms (Wulff and Maheshwari, 1938; Venkateswarlu, 1945 and 1947).

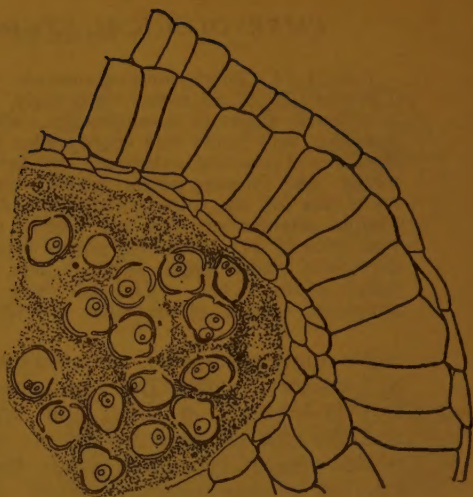
In both the plants studied the wall between the generative and vegetative nuclei disappears (Figs. 12 and 20). The mature pollen grain is three-nucleate. The two sperms are elongated and spindle-shaped and the chromatin in them is unevenly distributed (Figs. 13 and 21). There are three circular germ pores, one each in the middle of a germinal furrow. The pore membrane protrudes out in *Napoleona imperialis* (Fig. 22). In *Barringtonia*, it does not protrude but forms a small knob below the level of the surface of the pollen grain. The exine presents certain differences between the two plants. In *Napoleona imperialis*, the exine consists of light and dark staining portions as seen in sections. The dark staining portions take the form of radially arranged rods and light staining portions cover these on all sides. The exine in *Barringtonia acutangula* is formed into thickened rims where it is interrupted by the narrow furrows. Between the three furrows the exine is slightly bulged outward. It looks as though it is formed into three valves, the rimmed edges of which are separated by the narrow furrows. In the region of each germ pore the rim of each of the three exine plates bordering on the germ pore is raised in the form of a hood (Figs. 12 and 13). The surface of the exine is formed into a number of small 4- or 5-sided areas separated by raised ridges which meet each other (Fig. 14).

DEVELOPMENT AND STRUCTURE OF THE OVULE AND EMBRYO-SAC

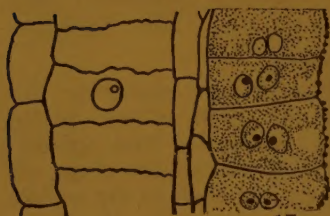
Ovule.—The ovules are borne in two rows in each of the locules of 5- or 6-chambered ovary of *N. imperialis*. The placentation is axile. The ovules are anatropous and two integumented (Fig. 41). The inner integument which alone forms the micropyle, appears first in the development of the ovule. It extends beyond the outer integument which is rather belated in its development. In the early stages they are about 5-7 cells thick. The inner, however, is a few more cells thick in its apical part which is swollen and club-shaped (Figs. 29 and 41). In advanced stages, the inner integument, except for a



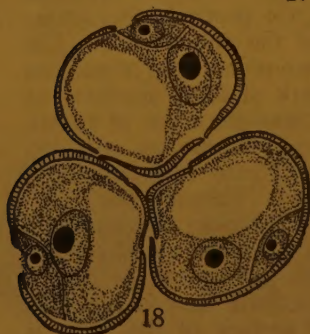
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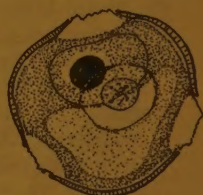
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FIGS. 15-25

FIGS. 15-25. *Napoleona imperialis*.—Fig. 15. T.S. of an anther lobe, $\times 430$. Fig. 16. T.S. of part of anther lobe showing amœboid tapetum surrounding the pollen grains, $\times 430$. Fig. 17. Part of L.S. of an anther lobe showing structure of the anther. Minute granular markings are seen on the inner walls of the tapetum, $\times 430$. Fig. 18. A pollen tetrad in which the pollen grains have not yet separated. The generative cell is cut off towards the outer wall in each of the pollen grains, $\times 1,010$. Figs. 19 and 20. Sections of 2-nucleate pollen grains. In the last the wall separating the generative cell has disappeared, $\times 1,010$. Fig. 21. Section of mature pollen grain showing the vegetative nucleus and the two spindle-shaped sperms, $\times 690$. Fig. 22. Entire pollen grain, $\times 1,010$. Fig. 23. An unusual pollen tetrad in which the pollen grains have not become free even when they are at the 3-nucleate stage, $\times 1,010$. Figs. 24 and 25. Sections of cases of pollen grains with 4 and 5 nuclei, $\times 1,010$.

few layers, is crushed and the outer becomes about 16-18 cells thick (Fig. 45). In the young ovule, the integuments seem to be fused with each other in the lower part (Fig. 41). In advanced stages they seem to fuse in the upper part also (Fig. 42). However, the cells of the regions formed by each integument are distinguishable from one another (Figs. 43 and 44). Therefore the above fusion seems to be due to a close juxtaposition of the integuments in the early stages of development.

One interesting feature is that the vascular bundle supplying the ovule does not end at the chalazal end of the nucellus as in most angiosperms, but travels beyond into the outer integument, on the side away from the raphe, upto its apical part (Fig. 42). In *Napoleona imperialis* this is unbranched (Fig. 44) as recorded in *Careya arborea*, *Barringtonia acuminata*, *B. asiatica*, *B. recemosa*, *B. speciosa*, *Gustavia augusta* and *Couroupita guianensis* (Mauritzon, 1939), but in *Barringtonia acutangula*, the vascular bundle branches into a number of traces at the chalazal end of the ovule and these run into the outer integument (Fig. 46). In advanced stages tracheids are found to be differentiated in these branches.

The nucellus in the ovules is very poorly developed. In the micropylar part, it is crushed by the embryo-sac which comes to border upon the mantle layer formed by the innermost cell layer of the inner integument (Fig. 46). In late stages of development of the embryo-sac the inner layers of the inner integument (Figs. 43 and 45) are also crushed.

Embryo-sac.—The cells lying at the apex of the nucellus in young ovules stain deeply and look like archesporial cells forming multicellular archesporium (Fig. 26). Usually, however, only one of the hypodermal archesporial cells enlarges and directly becomes the megaspore mother cell without cutting off a parietal cell (Figs. 27 and 29) as in the other investigated members of the family (Mauritzon, 1939).

Meiotic divisions take place in the megaspore mother cells giving rise to linear or T-shaped megaspore tetrads (Figs. 30, 31 and 32). The upper dyad is usually much smaller than the lower. The chalazal-most megaspore which is much larger than its sister cell develops into the embryo-sac. Usually only one megaspore tetrad is formed in the ovules of *Napoleona imperialis* but in a few cases ovules with 2 megaspore tetrads were encountered (Fig. 36) during the present study.



FIGS. 26-35. *Napoleona imperialis*.—Fig. 26. L.S. of young ovule showing many-celled archesporium, $\times 430$. Fig. 27. L.S. of an ovule with a single functional archesporial cell, $\times 430$. Fig. 28. L.S. of ovule with two functional archesporial cells, $\times 430$. Fig. 29. L.S. ovule showing M.M. cell, $\times 430$. Figs. 30, 31 and 32. Tetrads of megaspores, $\times 685$. Fig. 33. Four-nucleate embryo-sac. The upper part of the nucellus is completely destroyed, $\times 430$. Fig. 34. Three antipodal cells at the chalazal end of a young embryo-sac, $\times 430$. Fig. 35. An almost mature embryo-sac, $\times 430$.

An 8-nucleate embryo-sac is formed according to the Normal type. During its development it crushes the nucellar epidermis completely in the upper part of the ovule and comes to abut on the inner-

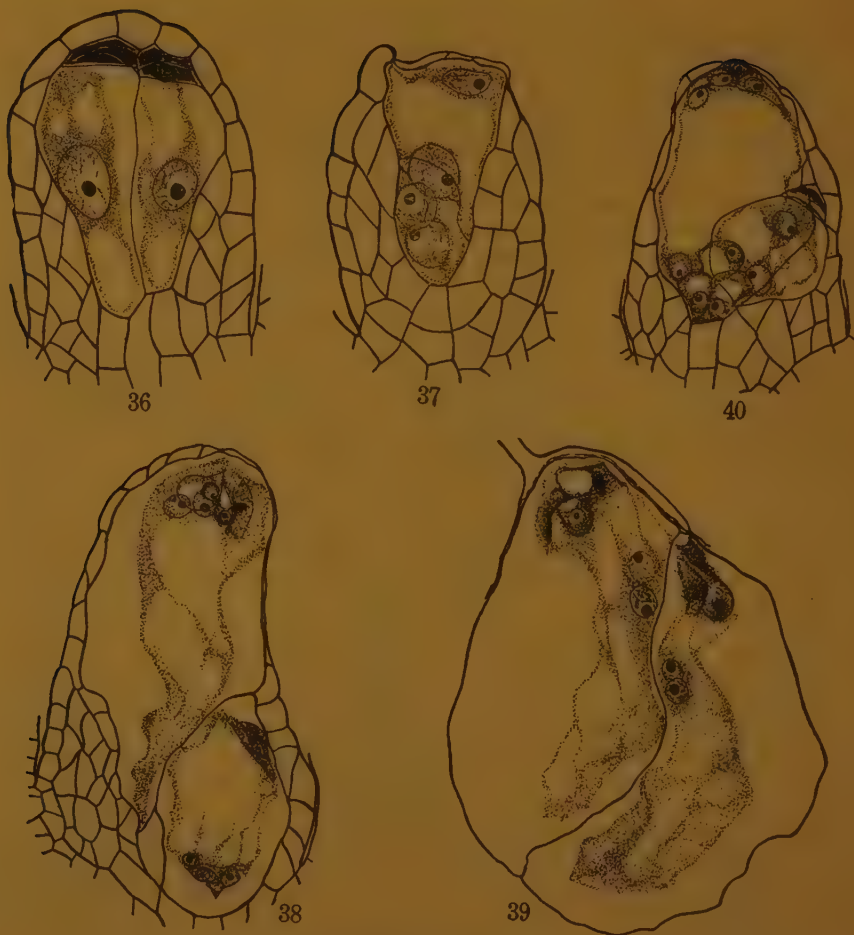
most layer of the inner integument which forms a tapetum. In old ovules this layer is also destroyed by the enlarging embryo-sac. The three antipodal cells which are seen in the early stages of the embryo-sac (Fig. 34) disappear soon and the mature embryo-sac shows the egg apparatus and the polar nuclei in the upper part. The synergids are pear-shaped and without hooks. In the species previously investigated by Mauritzon (1939), the antipodals were not observed and the structure of the embryo-sac was not described in detail. The present account, however, substantiates his surmise that the embryo-sac develops according to the Normal type and the antipodals degenerate very early.

DOUBLE EMBRYO-SACS

Usually, only one embryo-sac is developed in an ovule of *Napoleona imperialis*. Occasionally, however, ovules with two embryo-sacs have been met with (Figs. 36–40). The two embryo-sacs contained in the same ovule might originate either (i) from the functional megaspores of two separate megaspore tetrads occasionally developed in an ovule or (ii) from the further development of two megaspores of the single tetrad usually found in an ovule. Figs. 36 and 40 are clearly instances falling under the former category. In the cases sketched in Figs. 37–39 it is not possible to determine exactly as to which of the two explanations will hold good. As, however, no cases of ovules in which further development of two megaspores of a single tetrad have been met with during the present study, it is probable that even these have originated in the same way as the cases sketched in Figs. 36 and 40. In the cases shown in Figs. 36, 37 and 39 both the embryo-sacs in the particular ovules are at about the same stage of development, but in the cases shown in Figs. 38 and 40 they are at different stages of development. For instance in Fig. 38 one of the embryo-sacs is at an advanced stage in which the antipodals have already disappeared, while the other is at an earlier stage. In Fig. 40, one of the two embryo-sacs contained in the ovule is at the 2-nucleate stage, while the other is at the 8-nucleate stage and shows the egg apparatus and the antipodal cells.

REVERSED POLARITY

Fig. 40 shows an exceptional case of an ovule which, besides containing two embryo-sacs, shows reversal in the usual polarity characteristic of the normal embryo-sac. In the older of the two embryo-sacs the three antipodal cells are situated at the micropylar end of the embryo-sac along with a polar nucleus, while the egg apparatus and the other polar nucleus are at the micropylar end. The synergids can easily be made out by their pear-shaped form and the presence of basal vacuoles and the egg by its characteristic flask-shaped form and the prominent vacuole in its upper part. Reversed polarity in the embryo-sacs of angiosperms is very rare and the cases recorded so far are already listed by Dahlgren (1927), Schnarf (1929) and Swamy (1946). In *Myrtilloræ* reversed polarity has previously been recorded in *Fuchsia Marinka* by Tackholm (1915), in *Woodfordia floribunda* and

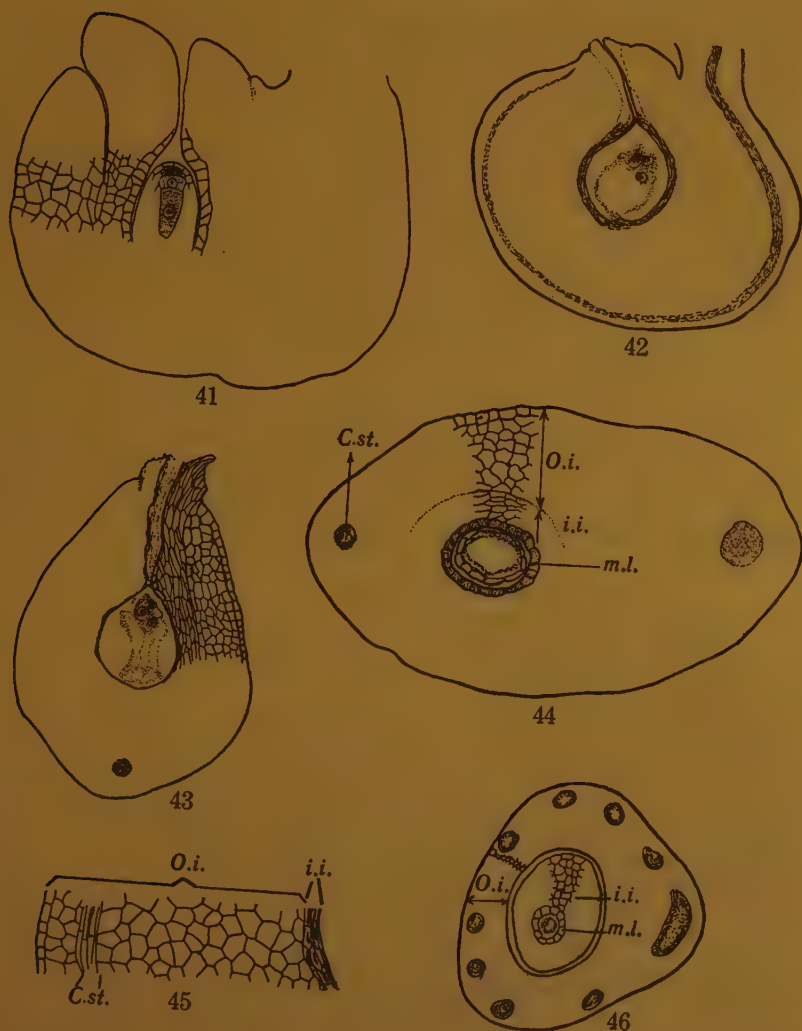


FIGS. 36-40. *Napoleonea imperialis*.—Figs. 36-39. Cases of ovules with two embryo-sacs (see text for detailed explanation), Figs. 36 and 37, $\times 685$; Figs. 38 and 39, $\times 430$. Fig. 40. Two embryo-sacs in an ovule, one of them showing reversed polarity, $\times 430$.

Lagerstræmia indica by Joshi and Venkateswarlu (1935 a, 1935 c) and in *Oenothera gigas* and *O. Lamarckiana* by Beth (1938).

DISCUSSION

The various members of the family Lecythidaceæ so far investigated show uniformity in their embryological features among themselves and stand apart from the rest of the families included in the order Myrtifloræ. However, in one or more of the features such as the presence of many potential archesporial cells and occasional occurrence of two megaspores, two megaspore tetrads and two embryo-sacs in an ovule



FIGO. 41-46. Figs. 41-45. *Napoleonaea imperialis* and Fig. 46. *Barringtonia acutangula*.—Fig. 41. L.S. of young ovule along the plane containing the funicle, $\times 195$. Fig. 42. L.S. of mature ovule in the same plane. The outer integument contains a vascular trace and the inner is destroyed to a great extent by the growth of the embryo-sac, $\times 45$. Fig. 43. L.S. ovule in a plane at right angles to that containing the funicle, $\times 108$. Fig. 44. T.S. ovule showing the vascular bundle in the outer integument, $\times 195$. Fig. 45. L.S. of the integuments in an old ovule showing a vascular strand in the outer integument (*o.i.*). The inner integument is almost completely destroyed, $\times 195$. Fig. 46. T.S. ovule showing branches of the vascular trace in the outer integument, $\times 108$.

C.st., Conducting strand (Vascular trace); *O.i.*, outer integument; *i.i.*, inner integument; *m.l.*, mantle layer.

and the early degeneration of the antipodals in the embryo-sac, Lecythidaceæ resembles Lythraceæ, Sonneratiaceæ (Joshi and Venkateswarlu, 1935 *b*, 1935 *c*, 1936; Mauritzon, 1934, 1939; Venkateswarlu, 1937), Rhizophoraceæ (Schnarf, 1931), Melastomaceæ (Subrahmanyam, 1934), Myrtaceæ (Tiwarý and Rao, 1934), Hydrocaryaceæ (Ishikawa, 1918). On the other hand, Lecythidaceæ shows certain distinctive features such as (i) an ovule with scanty nucellus and rather massive integuments, the outer with vascular trace or traces and (ii) the absence of a parietal cell in the ovule [only found in Hippuridaceæ and Cynomoriaceæ so far in Myrtifloræ according to Schnarf (1931)] and (iii) amœboid tapetum in the anther. Therefore the present study does not favour the inclusion of the genera of Lecythidaceæ in Myrtiaceæ as proposed by Bentham and Hooker (1862-83), but strongly supports the separation of these to form a family distinct from others within the Myrtifloræ.

Our knowledge of the structure and development of the anther and pollen is confined only to the present study based on two species distributed over two genera (*Napoleona* and *Barringtonia*) but the pollen characters seem to afford a criterion of distinction between the two genera and a comprehensive study of pollen in the family seems worthwhile from this point of view.

SUMMARY

The development and the structure of the anther, pollen, ovule and embryo-sac in *Napoleona imperialis* and the anther and pollen in *Barringtonia acutangula* are described in the paper.

The anther wall is 5-layered. The subepidermal layer develops into the fibrous endothecium and the innermost into the tapetum which is of the amœboid type. The median layers get crushed. Cytokinesis takes place by furrowing in the tetranucleate pollen mother cells and usually the pollen tetrads are tetrahedral. The pollen grains remain together till they are two-nucleate. The mature pollen is three-nucleate. The sperms are elongated and spindle shaped. The pollen grain shows three germ pores and three furrows. Some abnormal pollen grains and pollen tetrads are also met with.

The ovules are anatropous and bitegmic. The micropyle is formed by the inner integument alone. The nucellus is scanty and is destroyed by the embryo-sac, especially in the micropylar part. The integuments are thick and the outer contains a single vascular trace in *Napoleona imperialis*. In *Barringtonia acutangula*, the ovular trace branches into eight bundles at the base of the ovule and all these travel up into the outer integument. The inner integument is also destroyed to a great extent by the growing embryo-sac.

The primary archesporium in the ovule is multicellular but usually only one of the archesporial cells develops further and forms megaspore mother cell directly without cutting off a parietal cell. The megaspore tetrad is linear or T-shaped. The chalazal-most megaspore of the tetrad forms an eight-nucleate embryo-sac according to the Normal type. The antipodals degenerate early.

Cases of two megaspores, two megaspore tetrads and two embryo-sacs in an ovule are occasionally met with. A case of reversed polarity in one of the two embryo-sacs in an ovule of *Napoleona imperialis* is described.

Embryological evidence is in favour of treating Lecythidaceæ as a family distinct from the rest included in the order Myrtifloræ and against inclusion of the genera concerned in Myrtaceæ.

The writer is indebted to Dr. I. Banerji of the Calcutta University and Mr. R. M. Dutta, Calcutta, for a part of the material of *Napoleona imperialis* used in this investigation. He is thankful to Prof. A. C. Joshi for his kind interest in the work.

LITERATURE CITED

- BENTHAM, G. AND HOOKER, J. D. 1862-83. *Genera Plantarum*, London.
- BETH, K. 1938. Untersuchungen über die Auslösung von Adventitive embryonie durch wundreiz. *Planta*. 28: 296-343.
- BHARGAVA, H. R. 1936. The Life-History of *Chenopodium album* Linn. *Proc. Ind. Acad. Sci. B*. 4: 179-200.
- DAHLGREN, K. V. O. 1927. Die Befruchtungsercheinungen der Angiospermen. *Hereditas*. Lund 10: 169-229.
- ENGLER, A. AND PRANTL, K. 1892. *Die Natürlichen Pflanzenfamilien*. III: 7.
- HUTCHINSON, J. 1926. *The Families of Flowering Plants*. Vol. I. Dicotyledons, London.
- ISHIKAWA, M. 1918. Studies on the embryo-sac and fertilisation in *Oenothera*. *Ann. Bot.* 32: 279-317.
- JOSHI, A. C. AND VENKATESWARLU, J. 1935 a. A case of Reversed polarity in Embryo-sac. *Ann. Bot.* 49: 841-843.
- . 1935 b. Embryological studies in the Lythraceæ. I. *Lawsonia inermis* Linn. *Proc. Ind. Acad. Sci. B*. 2: 481-493.
- . 1935 c. Embryological studies in the Lythraceæ. II. *Lagerstræmia* Linn. *Proc. Ind. Acad. Sci. B*. 2: 523-534.
- KAJALE, L. B. 1940. A contribution to the embryology of the Amarantaceæ. *Proc. Nat. Inst. Sci. India*. 6: 597-625.
- KOSMATH, L. 1927. Studien über das Antherentapetum. *Osterr. Bot. Ztschr.* 76: 235-341.
- MAURITZON, J. 1934. Zur Embryologie einiger Lythraceen. *Meddelanden Göteborgs Botaniska Trädgård*. 9: 1-21.
- . 1939. Contributions to the embryology of the orders Rosales and Myrtales. *Lund. Univ. Årsskrift. N.F. Avd. 2*, 35: 1-120.
- NARASIMHAMURTY, K. L. 1938. Gametogenesis and embryology in some Commelinaceæ. *Journ. Ind. Bot. Soc.* 17: 101-116.
- RENDLE, A. B. 1925. *The Classification of Flowering Plants*. Vol. II. Dicotyledons. Cambridge Univ. Press.
- SCHNARF, K. 1929. *Embryologie der Angiospermen*. Berlin.
- . 1931. *Vergleichende Embryologie der Angiospermen*. Berlin.
- SANE, Y. K. 1939. A contribution to the embryology of Aponogetonaceæ. *Jour. Ind. Bot. Soc.* 18: 79-91.
- SUBRAHMANYAM, K. 1934. Gametogenesis and Embryogeny in a few members of the Melastomaceæ. *Jour. Ind. Bot. Soc.* 21: 69-85.

- SWAMY, B. G. L. 1946. Inverted polarity of the Embryo-sac of Angiosperms and its relation to the Archegonium theory. *Ann. Bot. N.S.* 10: 171-183.
- TACKHOLM, G. 1915. Beobachtungen über die Samenentwicklung einiger onagra-ceen. *Svensk Bot. Tidskr.* 9: 294-361.
- TISCHLER, G. 1915. Die Periplasmodienbildung in den Antheren der Commelinaceen und Ausblick auf das Verhalten der Tapetenzellen bei den übrigen Monocotylen. *Jahrb. f. Wiss. Bot.* 55: 52-90.
- TREUB, M. 1884. L'embryon du *Barringtonia vriesii* T et B. *Ann. Jard. Buitenzorg.* 4: 101-106.
- TIWARI, N. K. AND RAO, V. S. 1934. A preliminary note on the embryo-sac development of *Callistemon linearis*. *Curr. Sci.* 2: 339.
- UBISCH, G. V. 1927. Zur Entwicklungsgeschichte der Antheren. *Planta.* 3: 490-495.
- VENKATESWARLU, J. 1937. A contribution to the embryology of Sonneratiaceæ. *Proc. Ind. Acad. Sci. B.* 5: 206-223.
- . 1945. Embryological studies in the Thymelæaceæ. I. *Thymelæa arvensis* Lamk. *Jour. Ind. Bot. Soc.* 24: 45-66.
- . 1947. Embryological studies in the Thymelæaceæ. II. *Daphne cannabina* Wall. and *Wikstræmia canescens* Missn. *Jour. Ind. Bot. Soc.* 26: 13-39.
- WETTSTEIN, R. 1935. *Handbuch der Systematischen Botanik.* Leipzig und Wien.
- WULFF, H. D. AND MAHESHWARI, P. 1938. The male Gametophyte of Angiosperms—A Critical Review. *Jour. Ind. Bot. Soc.* 17: 117-140.

A SYSTEMATIC ACCOUNT OF THE DIATOMS OF BOMBAY AND SALSETTE

PART I

Centrales : Sub-order—Discineæ and

**Pennales : Sub-orders—Araphidineæ, Raphidioidineæ,
Monoraphidineæ and Biraphidineæ.**

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INTRODUCTION

IN a comprehensive review of the available literature on Diatomaceæ, Patrick¹ has surveyed the information on diatoms given previously by other workers. The only records of diatoms from India included in the bibliography given by her are those of Biswas,² Majeed³ and Skvortzow.⁴ These are records of diatoms from North India only. Very admirable accounts of diatoms from South India are given by Venkataraman⁵ and Subrahmanyam.⁶ The former has surveyed the literature dealing with systematic accounts of diatoms in India, previous to the publication of his paper and mentions that all the references obtained till then relate to the diatoms of Upper India. As far as South India is concerned, these two workers have made up for any deficiencies by their admirable and very well-illustrated accounts of fresh-water, brackish-water and marine diatoms from South India. From the data given by Venkataraman,⁵ the fact emerges that no record of the diatoms of Bombay or of the Bombay State exists. It was in order to rectify this omission that the present investigation was undertaken. At first it was meant to be a survey of the diatoms of Bombay State, but as the number of diatoms found in Bombay and its environs alone was formidable, the survey was restricted to these areas only.

The investigation was carried out in the Botany Departments of the Institute of Science, Bombay, and the Karnatak College, Dharwar.

¹ Bot. Rev. 1948. 14: 473-524.

² Jour. Roy. Asiatic Soc. of Bengal. 1936. 2: 171-175.

³ Freshwater Algæ of the Panjab. Part I. Bacillariophyta, Diatomæ, Panjab University Publications, Lahore, 1935.

⁴ Phil. Jour. Sci. 1935. 58: 179.

⁵ Proc. Ind. Acad. Sci. 1939. B. 10: 293-368.

⁶ Proc. Ind. Acad. Sci. 1946. B. 24: 85-197.

Collections of diatoms were made from various tanks, ponds and streams, chiefly in Salsette, which is an island connected with that of Bombay. Very good collections were also obtained from the temporary rain-water pools and puddles, so common in and around Bombay during the monsoons. The brackish-water forms were collected chiefly from the Mahim and Chembur creeks.

The drawings of the forms were made from specimens prepared by adopting the method described by Venkataraman (1939).

A total of 267 forms have been recorded from this area. These represent 32 genera and include 10 new species, 21 new varieties and 40 new forms. In this paper, 61 forms are described. The remaining will be described in the subsequent papers of this series.

The authors record their grateful thanks to Prof. M. O. P. Iyengar, Madras, for his helpful suggestions in connection with the preparation of this paper and to Dr. T. S. Sadasivan, Madras, and Prof. V. V. Apte, Poona, for their generous help with literature. Very sincere thanks are also due to Rev. Fr. H. Santapau, Bombay, and Principal A. Menezes, Dharwar, for the Latin diagnoses of the new forms.

Bacillariophyta (Diatomeæ)

A. Order	<i>CENTRALES</i>
I. Suborder	<i>DISCINEÆ</i>
(1) Family	<i>COSCINODISACEÆ</i>
(a) Subfamily	<i>Melosiroideæ</i>
Genus	<i>Melosira</i> Agardh, 1824.

1. *Melosira Juergensi* C. A. Ag.

(Fig. 1)

Van Heurck, H., *Traité des Diatomées*, 1899, p. 442, pl. 28, fig. 612; Migula, W., *Kryptogamen-Flora*, Bd. VI, Teil 1 a, p. 153, Taf. 17, fig. 5; Gran, H. H., *Nordisches Plankton, Botanischer Teil*, Bd. VIII, 1909, p. 12, pl. 19, fig. 2; Schönfeldt, Pascher's *Süsswasser-Flora*, Heft 10, 1913, p. 15, fig. 1; Hustedt, Fr., Pascher's *Süsswasser-Flora*, Heft 10, 1930, p. 84, fig. 40; Hustedt, Fr., Rabenhorst's *Kryptogamen-Flora*, Bd. VII, Teil 1, 1930, pp. 238-39, fig. 99.

Frustules cylindrical, united in long chains. Outer mantle line straight, inner slightly wavy. Neck absent. Cell wall strong and punctate in spiral rows.

Dimensions ..	Diameter of the cell 23-25 μ
	Height of half cell 21.5-24 μ
	Rows of puncta 28-29 in 10 μ

Habitat .. Fresh-water. Powai lake. Common.

2. *Melosira granulata* (Ehr.) Ralfs.

(Fig. 2)

Van Heurck, H., *Traité des Diatomées*, 1899, p. 119, fig. 621; Schönfeldt, Pascher's *Süßwasser-Flora*, Heft 10, 1913, p. 16, fig. 9; Krieger, W., Kolkwitz's *Pflanzenforschung*, Heft 10, 1927, Taf. 1, fig. 1; Hustedt, Fr., Pascher's *Süßwasser-Flora*, Heft 10, 1930, p. 87; fig. 44; Hustedt, Fr., Rabenhorst's *Kryptogamen-Flora*, Bd. VII, Teil 1, 1930, p. 248, figs. 104, a, b, c, e; Skvortzow, B. W., Diatoms from Poyang Lake, Hunan, China, *Phil. Jour. Sci.*, Vol. 57, 1935, p. 465, pl. 1, fig. 4; Diatoms from Kizaki Lake, Honshu Island, Nippon, Vol. 61, 1936, p. 9, pl. 1, fig. 8.

Frustules cylindrical, united in chains. Mantle line straight. Mantle portion well developed. Neck fairly large. Mantle surface straight and parallel. Surface of the mantle punctate with puncta in spiral rows. End cell with coarser puncta in parallel rows and also long spines directed inwards and outwards.

- Dimensions .. Diameter of the cell 8–10 μ
 Height of half-cell 9–13 μ
 Rows of puncta 9–10 in 10 μ
 No. of puncta 9–11 in 10 μ
 No. of puncta in the end cell 8–9 in 10 μ
- Habitat .. Fresh-water. Streams at Borivli. Common.
 Brackish water. Mahim creek. Rare.

3. *Melosira granulata* (Ehr.) Ralfs var. *muzzanensis* Meister

(Fig. 3)

Bethge, H., Kolkwitz's *Pflanzenforschung*, Heft 13, 1925, p. 32, fig. 5; Hustedt, Fr., Pascher's *Süßwasser-Flora*, Heft 10, 1930, p. 88, fig. 47; Hustedt, Fr., Rabenhorst's *Kryptogamen-Flora*, Bd. VII, Teil 1, 1930, p. 251, fig. 105; Skvortzow, B. W., Diatoms from Biwa Lake, Honshu Island, Nippon. *Phil. Jour. Sci.*, Vol. 61, 1936, p. 253, pl. 1, fig. 20.

Frustules short cylindrical, flat, united in chains by gelatinous cushions. Edges of the valves rounded. Neck large. Mantle line straight and parallel. Wall coarsely punctate in spiral rows. End cell coarsely punctate in straight rows. The spines project outside and inside in the same cell.

- Dimensions .. Diameter of the cell 18–20 μ
 Height of the cell 12–13 μ
 Rows of puncta 12–13 in 10 μ
 No. of puncta 18–20 in 10 μ
- Habitat .. Fresh-water. Streams at Borivli. Not very common.

4. *Melosira islandica* O. Müll. subspecies *helvetica* O. Müll

(Fig. 4)

Hustedt, Fr., Pascher's *Süsswasser-Flora*, Heft 10, 1930, p. 89, fig. 48; Hustedt, Fr., Rabenhorst's *Kryptogamen-Flora*, Bd. VII, 1930, Teil 1, p. 254, fig. 107; Skvortzow, B. W., Diatoms from Ikeda-Lake, Satsuma Province, Kiewisien Island, Nippon, *Phil. Jour. Sci.*, Vol 62, 1937, p. 191, pl. 2, fig. 13.

Frustules cylindrical, united in chains. Valves thin with parallel margins. Neck ring-like. Wall clearly punctate in straight rows.

Dimensions .. Diameter of the cell 8-9 μ
 Height of half-cell 12-13 μ
 Rows of puncta 13-14 in 10 μ
 No. of puncta 15-16 in 10 μ

Habitat .. Fresh-water. Streams at Borivli. Common.

(b) *Subfamily* Coscinodiscoideæ

Genus *Cyclotella* Kützing, F. T., 1834.

5. *Cyclotella stelligera* Cleve et Grun.

(Fig. 5)

Schönfeldt, Pascher's *Süsswasser-Flora*, Heft 10, 1913, p. 18, fig. 13; Hustedt, Fr., Pascher's *Süsswasser-Flora*, Heft 10, 1930, p. 100, fig. 65; Hustedt, Fr., Rabenhorst's *Kryptogamen-Flora*, Bd. VII, Teil 1, 1930, p. 339, fig. 172; Skvortzow, B. W., Diatoms from Kizaki Lake, Honshu Island, Nippon. *Phil. Jour. Sci.*, Vol. 61, 1936, p. 9, pl. 1, fig. 11; Diatoms from the Phillipine I. Diatoms from Drinking Water, Balara, Rizal Province, Vol. 64, 1937, p. 287, pl. 1, fig. 36; Venkataraman, G., A. Systematic Account of Some South Indian Diatoms, *Proc. Ind. Acad. Sci.* Vol. X, No. 6, Sect. B, 1939, p. 298, fig. 10.

Frustules almost discoid. Margin with coarse radiating striæ. The middle field has a punctum in the centre and short, thick radiating lines forming a star-like structure.

Dimensions .. Diameter of the cell 9.5-11 μ
 Striæ 9-10 in 10 μ

Habitat .. Fresh-water. Streams at Borivli, Powai lake.
 Not common.

6. *Cyclotella Meneghiniana* Kütz.

(Fig. 6)

Van Heurck, H., *Traité des Diatomées*, 1899, p. 447, pl. 22, fig. 656; Migula, W., *Kryptogamen-Flora*, Bd. II, Teil 1 a, p. 155, Taf. 17, fig. 10; Schönfeldt, Pascher's *Süsswasser-Flora*, Heft 10, 1913, p. 19, fig. 17; Gustav, L., *Die Algen*, 1914, p. 135, fig. 229; Hustedt, Fr., Pascher's *Süsswasser-Flora*, Heft 10, 1930, p. 100, fig. 67; Hustedt, Fr., Rabenhorst's *Kryptogamen-Flora*, Bd. VII, Teil 1, 1930, p. 341,

fig. 174; Skvortzow, B. W., Diatoms from Poyang Lake, Hunan, China, *Phil. Jour. Sci.*, Vol. 57, 1935, p. 465, pl. 1, fig. 1; Venkataraman, G., A Systematic Account of Some South Indian Diatoms, *Proc. Ind. Acad. Sci.* Vol. X, No. 6, Sect. B, 1939, p. 299, figs. 11, 14; Iyengar and Subrahmanyam, Fossil Diatoms from the Karewa Beds of Kashmir, *Proc. National Acad. Sci.*, India, Vol. 13, pt. 4, p. 226–27, figs. 1–2; Subrahmanyam, R., Marine Plankton Diatoms of the Madras Coast, *Proc. Ind. Acad. Sci.*, Vol. 24, No. 4, Sect. B, 1946, p. 92, figs. 25–27.

Frustules in girdle view rectangular with wavy walls. Valves discoid, margins strong. Striæ thick and coarse, wedge-shaped and radially placed. Central portion with extremely fine puncta arranged in radiating rows.

Dimensions .. Diameter of the cell 18–20 μ
Striæ 8–9 in 10 μ

Habitat .. Fresh-water. Borivli streams and Powai Lake.
Rare. Brackish-water. Mahim and Chembur
Creeks. Common.

7. *Cyclotella striata* (Kütz.) Grun.

(Fig. 7)

Van Heurck, H., *Traité des Diatomées*, 1899, p. 444, pl. XXII, fig. 651, Hustedt, Fr., Pascher's *Süßwasser-Flora*, Heft 10, 1930, p. 101, fig. 71; Hustedt, Fr., Rabenhorst's *Kryptogamen-Flora*, Bd. VII, Teil 1, 1930, p. 344, fig. 176; Skvortzow, B. W., Marine Diatoms from the Kanazawo Oyster Experimental Station of Japan, *Phil. Jour. Sci.*, Vol. 47, 1932, p. 119, pl. 2, fig. 3; Marine Littoral Diatoms from the environs of Vladivostock, p. 129, pl. 1, figs. 6–9; Subrahmanyam, R., Marine Plankton Diatoms of the Madras Coast, *Proc. Ind. Acad. Sci.*, Vol. XXIV, No. 4, Sect. B, 1946, p. 92, fig. 31.

Cells disc-shaped. Valves with strong wavy margins in girdle view and more or less broad, evenly striated border. Central portion with pflaxes and coarse puncta.

Dimensions .. Diameter of the cell 21·6–32·4 μ
Striæ 8–9 in 10 μ

Habitat .. Brackish-water. Mahim-Creek. Abundant.

8. *Cyclotella striata* (Kütz.) Grun. var. *bipunctata* Fricke

(Fig. 8)

Hustedt, Fr., Pascher's *Süßwasser-Flora*, Heft 10, 1930, p. 102, fig. 72; Hustedt, Fr., Rabenhorst's *Kryptogamen-Flora*, Bd. VII, Teil 1, 1930, p. 346, fig. 176 c; Skvortzow, B. W., Marine Diatoms from the Kanazawo Oyster Experimental Station of Japan, *Phil. Jour. Sci.*, Vol. 47, 1932, p. 119, pl. 2, fig. 4.

This form agrees in all respects with the species except that the cell is smaller and the central area has only two very conspicuous puncta.

Dimensions	..	Diameter of the cells 21-23 μ Striæ 8-10 in 10 μ
Habitat	..	Brackish-water. Mahim-Creek. Common.

9. *Cyclotella catenata* Brun.

(Fig. 9)

Hustedt, Fr., Pascher's *Süsswasser-Flora*, Heft 10, 1930, p. 108, fig. 83; Hustedt, Fr., Rabenhorst's *Kryptogamen-Flora*, Bd. VII, Teil 1, 1930, p. 365, fig. 191.

Frustules formed in chains. Valves arched, centric and small. The convex surface is slightly depressed in the middle. Striæ strong and wedge-shaped, radial. In the middle field large puncta are present forming radial striæ, short and long striæ alternating with one another.

Dimensions .. Diameter of the cell 11-18 μ
Striae 12 in 10 μ

Habitat . . . Fresh-water. Powai Lake. Not common.

Genus *Coscinodiscus* Ehrenberg, C. G., 1838

10. *Coscinodiscus radiatus* Ehr.

(Fig. 10)

Van Heurck, H., *Traité des Diatomées*, 1899, p. 520, pl. 23, fig. 663; Gran, H. H., *Nordisches Plankton, Botanischer Teil*, Bd. VIII, 1908, pl. XIX, fig. 30; Lebour Marie, V., *Planktonic Diatoms of Northern Seas*, 1930, p. 39, fig. 15; Skvortzow, B. W., *Pelagic Diatoms of Korean Strait of the Sea of Japan*, *Phil. Jour. Sci.*, Vol. 46, 1931, p. 95, pl. 1, fig. 3; Marine Littoral Diatoms from the Environs of Vladivostok, Vol. 47, 1931, p. 129, pl. 2, figs. 2-4, Bottom Diatoms from Olhon Gate of Baikal Lake, Siberia, Vol. 62, 1936, p. 293, pl. 2, figs. 17-18.

Frustules in girdle zone low with no intercalary bands; surfaces slightly convex. Valves circular without any apicules or spinules. Aeriotes coarse and strong meshes of about the same size, slightly radiating from the centre to the margins. Aeriotes smaller at the extreme end.

Dimensions	..	Diameter of the cell 95-125 μ No. of aerioles in the middle 4-5 in 10 μ No. of aerioles at the margin 5-6 in 10 μ
Habitat	..	Brackish-water. Mahim and Chembur Creeks. Not common.

B. Order	PENNALES
I. Suborder	ARAPHIDINEÆ
(1) Family	FRAGILARIACEÆ
(a) Subfamily	Fragilarioideæ
Genus	<i>Ceratoneis</i> Kützinger, F. T.

11. *Ceratoneis Iyengarii* sp. nov.

(Fig. 11)

Frustula solitaria libere fluctuantia. Valvæ fortissime arcuatae, prominenter tumescentes ad lateres concavi medium, tenuissime decalescentes a medio in utrumque apicem qui obtuse rotundus est. Raphe in utraque valva abest. Pseudoraphe uniformiter lata et distincta, aliquantum ex medio exorbitans. Area centralis unilateralis adest, sed indistinctissimis punctis signatæ. Striæ radiatæ et distincta punctatæ. Longit 63–67 μ ; latit 12–6–13 μ ; Striæ 8 in 10 μ .

Frustules solitary, free-floating. Valves very strongly arcuate with a prominent gibbosity in the middle of the concave side, tapering very slightly from the middle towards the poles which are broadly rounded. Raphe absent on both valves. Pseudoraphe uniformly broad and distinct, somewhat excentric. Unilateral central area present, but marked with indistinct scattered puncta. Striæ radial and distinctly punctate.

Dimensions .. Length 63–67 μ
 Breadth 12·6–13 μ
 Striæ 8 in 10 μ

Habitat .. Brackish-water. Mahim Creek. Rare.

This form differs from *Ceratoneis arcus* Kutz. (Hustedt, in A. Pascher's *Süsswasser-Fl.*, p. 134, fig. 122) in being very strongly arcuate. Moreover it tapers very slightly towards the ends which are bluntly rounded. The striæ are distinctly punctate and more distantly placed. In the unilateral central area, indistinct, scattered puncta are seen. As it differs in so many respects, it is regarded as a new species.

Genus *Fragilaria* Lyngbye, 181912. *Fragilaria intermedia* Grun. var. *robusta* Venkataraman

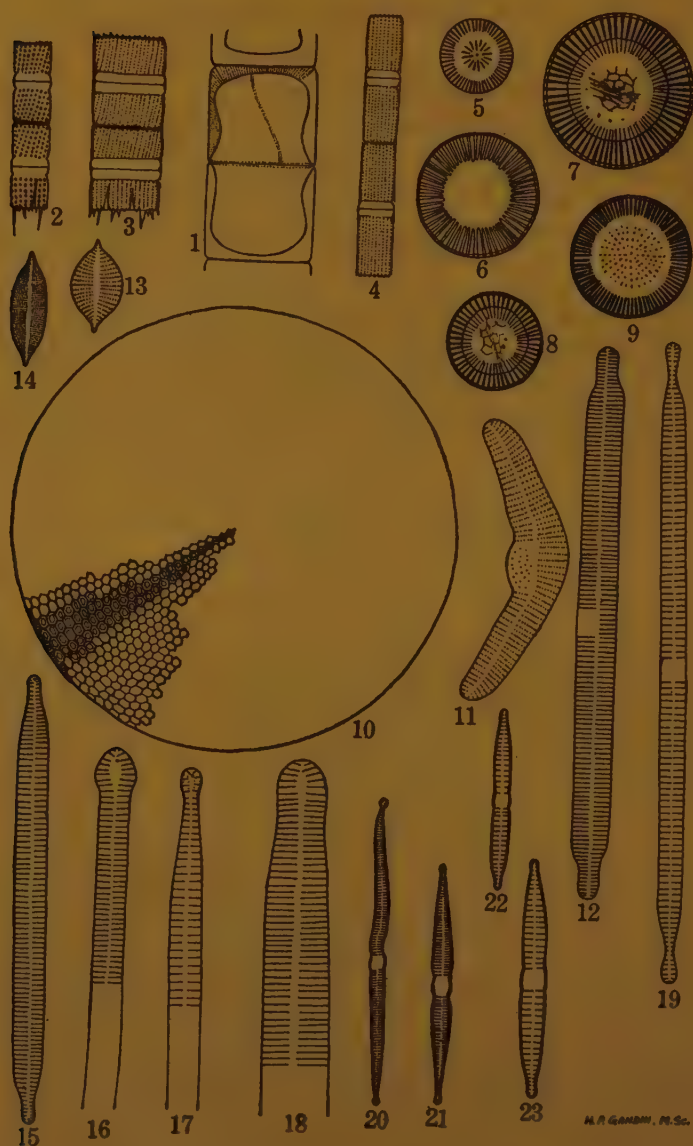
(Fig. 12)

Venkataraman, G., A Systematic Account of Some South Indian Diatoms, *Proc. Ind. Acad. Sci.*, Vol. X, No. 6, Sect. B, 1939, p. 304, figs. 27, 42.

Frustules in girdle view linear-rectangular, united by their margins to form long bands. Valves linear with parallel margins. Ends gradually tapering and rounded, very slightly capitate. Striæ coarse and distinct, in the middle absent on one side. Axial area narrow, linear.

Dimensions .. Length 95–119 μ
 Breadth 6–7·2 μ
 Striæ 9–10 in 10 μ

Habitat .. Fresh-water. Streams at Borivli and Powai Lake, Common.



H. P. GANDHI, M.Sc.

FIGS. 1-23. Fig. 1. *Melosira Juergensi* C. A. Ag., $\times 630$. Fig. 2. *Melosira granulata* (Ehr.) Ralfs, $\times 630$. Fig. 3. *Melosira granulata* (Ehr.) Ralfs var. *muzzanensis* Meister, $\times 630$. Fig. 4. *Melosira islandica* O. Müll, subspecies *helvetica* O. Müll, $\times 630$. Fig. 5. *Cyclotella stielhgeri* Cleve et Grun., $\times 1,000$. Fig. 6. *Cyclotella Meneghiniana* Kütz., $\times 1,000$. Fig. 7. *Cyclotella striata* (Kütz.) Grun., $\times 630$. Fig. 8. *Cyclotella striata* (Kütz.) Grun. var. *bipunctata* Fricke, $\times 630$. Fig. 9. *Cyclotella catenata* Brun., $\times 1,000$. Fig. 10. *Coscinodiscus radiatus* Ehr.,

×630. Fig. 11. *Ceratoneis Iyengarii* sp. nov., ×630. Fig. 12. *Fragilaria intermedia* Grun. var. *robusta* Venkataraman, ×630. Fig. 13. *Raphoneis ampiceros* Ehr., ×630. Fig. 14. *Raphoneis ampiceros* Ehr. f. *linearis* f. nov., ×630. Fig. 15. *Synedra ulna* (Nitz.) Ehr., ×630. Fig. 16. *Synedra ulna* (Nitz.) Ehr. var. *biceps* Kütz., ×630. Fig. 17. *Synedra ulna* (Nitz.) Ehr. var. *danica* (Kütz.) Grun., ×1,000. Fig. 18. *Synedra ulna* (Nitz.) Ehr. var. *subæqualis* Grun., ×1,000. Fig. 19. *Synedra ulna* (Nitz.) Ehr. var. *amphirhynchus* (Ehr.) Grun., ×630. Fig. 20. *Synedra rumpens* Kütz., ×630. Fig. 21. *Synedra rumpens* Kütz. var. *familiaris* (Kütz.) Grun., ×630. Fig. 22. *Synedra rumpens* Kütz. var. *fragilarioides* Grun., ×630. Fig. 23. *Synedra rumpens* Kütz. var. *Meneghiniana* Grun., ×1,000.

This form agrees with *F. intermedia* var. *robusta* Venkataraman, in all respects, except that the striæ are more distantly placed. The ends also seem to be more prolonged.

Genus *Raphoneis* Ehrenberg

13. *Raphoneis ampiceros* Ehr.

(Fig. 13)

Hustedt, Fr., Rabenhorst's *Kryptogamen-Flora*, Bd. VII, Teil II, 1931–32, p. 174, fig. 680; Subrahmanyam, R., Marine Plankton Diatoms of the Madras Coast, *Proc. Ind. Acad. Sci.*, Vol. 24, No. 4, Sect. B, 1946, p. 165, figs. 340–41.

Raphoneis rhombica, Van Heurck, *Traité des Diatomées*, 1899, p. 330, pl. 10, fig. 395.

Raphoneis rhombus, Roper, F. C. S., *Trans. Roy. Micros. Soc. Lond.*, N. Ser., Vol. 2, 1854, p. 67, pl. 6, fig. 10.

Fragilaria ampiceros, Migula, W., *Kryptogamen-Flora*, Bd. II, Teil I a, p. 189, Taf. 13, Fig. 1; Karsten, G., Engler and Prantl's *Natur. Pflanzen.*, Bd. II, 1928, p. 262, fig. 338; Gustav, L., *Die Algen*, 1914, p. 144, pl. 10, fig. 262.

Frustules unicellular, free-living or in gelatinous masses, rectangular in girdle view. Valves broadly elliptical. Ends produced and acutely rounded. Pseudoraphe distinct, narrow, lanceolate. Striæ with large moniliform puncta, slightly radiating.

Dimensions .. Length 19–22 μ
 Breadth 9–10 μ
 Striæ 7–10 in 10 μ
 Puncta 10 in 10 μ .

Habitat .. Brackish-water. Chembur Creek. Not common.

This form is smaller than the type, but in all other respects, it agrees with it.

14. *Raphoneis ampiceros* Ehr. f. *linearis* f. nov.

(Fig. 14)

Valvae lineares ellipticæ, graciliores atque notis tenuioribus ornatae quam in specie typica; striæ propius inter se dispositæ; puncta tenuissima sed distincta. Longit. 21–24 μ ; latit. 7.6 μ ; striæ 20–24 in 10 μ .

Valves linear-elliptical, more slender than the type with finer markings. The striae are more closely arranged. Puncta very fine but distinct.

Dimensions .. Length 21-24 μ
 Breadth 7.6 μ
 Striae 20-24 in 10 μ

Habitat .. Fresh-water. Pools at Wadala. Rare.

This form is distinctly linear-elliptical and slender, unlike the type. The striae also are very closely placed, fine and distinctly punctate. It is, therefore, regarded as a new form.

Genus *Synedra* Ehrenberg, C. G., 1830

15. *Synedra ulna* (Nitzsch) Ehr.

(Fig. 15)

Van Heurck, H., *Traité des Diatomées*, 1899, p. 310, pl. 10, fig. 409; Migula, W., *Kryptogamen-Flora*, Bd. II, Teil 1 a, p. 193, Taf. XI, figs. 14-16; Schönfeldt, Pascher's *Süsswasser-Flora*, Heft 10, 1913, p. 38, fig. 60; Gustav, L., *Die Algen*, 1914, p. 147, pl. 10, fig. 270; Konrad, G., Kolkwitz's *Pflanzen*, Heft 6, 1926, p. 1, fig. 3; Hustedt, Fr., Pascher's *Süsswasser-Flora*, Heft 10, 1930, p. 151, figs. 158-59; Hustedt, Fr., Rabenhorst's *Kryptogamen-Flora*, Bd. VII, Teil 2, Lief 1-4, 1931-32, p. 195, fig. 691 A a-c; Biswas, K., Common Diatoms of the Loktak Lake, Manipur, Assam, *Jour. Roy. Asia. Soc. Bengal*, Vol. 2, 1936-37, p. 173, pl. 5, fig. 8; Venkataraman, G., A Systematic Account of Some South Indian Diatoms, *Proc. Ind. Acad. Sci.*, Vol. 10, No. 6, Sect. B, 1939, p. 305, fig. 37.

Frustules linear in girdle view with a slight expansion at the poles. Valves linear to linear-lanceolate and tapering at the poles. Ends rounded. Pseudoraphe narrow, linear. Central area absent (in some cases present, reaching the margins). Striae coarse.

Dimensions .. Length 93-150 μ
 Breadth 7-8 μ
 Striae 9-10 in 10 μ

Habitat .. Fresh-water. Streams at Borivli, Powai Lake and other pools in its vicinity. Very common.

16. *Synedra ulna* (Nitzsch) Ehr. var. *biceps* Kütz.

(Fig. 16)

Hustedt, Fr., Pascher's *Süsswasser-Flora*, Heft 10, 1930, p. 154, fig. 166; Fritsch, F. E., and Rich, F., Contribution to Our Knowledge of the Fresh-water Algæ of Africa. Bacillariales (Diatoms) from Griqualand, West., *Trans. Roy. Soc. S. Africa*, Vol. 18, 1930, p. 97, fig. 2 r-t; Hustedt, Fr., Rabenhorst's *Kryptogamen-Flora*, Bd. VII, Teil 2, Lief 1-4, 1931-32, p. 195; Skvortzow, B. W., Diatoms from

Poyang Lake, Hunan, China, *Phil. Jour. Sci.*, Vol. 57, 1935, p. 465, pl. 1, fig. 11; Diatoms from Kizaki Lake, Honshu Island, Nippon, Vol. 61, 1936, p. 9.

Valves very long, slightly bent, linear, very slightly narrowed towards the ends. Ends broadly rounded, capitate. Striæ strong.

Dimensions .. Length 367–400 μ
 Breadth 5.4–6 μ
 Striæ 8–9 in 10 μ

Habitat .. Fresh-water. Streams at Borivli. Common.

17. *Synedra ulna* (Nitzsch) Ehr. var. *danica* (Kütz.) Grun.

(Fig. 17)

Van Heurck, H., *Traité des Diatomées*, 1899, p. 311, pl. 11, fig. 415; Hustedt, Fr., Pascher's *Süßwasser-Flora*, Heft 10, 1930, p. 154, fig. 168; Hustedt, Fr., Rabenhorst's *Kryptogamen-Flora*, Bd. VII, Teil 2, Lief 1–4, 1931–32, p. 195; Skvortzow, B. W., Diatoms from Khingan, North Manchuria, China. *Phil. Jour. Sci.*, Vol. 35, 1928, p. 39, pl. 1, figs. 19–20; Diatoms from Kizaki Lake, Honshu Island, Nippon, Vol. 61, 1936, p. 9, pl. 10, fig. 10.

Valves slender and strongly narrowed at the ends which are constricted and somewhat rounded and capitate. Striæ strong and uniformly placed.

Dimensions .. Length 298–310 μ
 Breadth 4–5 μ
 Striæ 9–10 in 10 μ

Habitat .. Fresh-water. Powai Lake. Garden tank of Institute of Science, Bombay. Common.

18. *Synedra ulna* (Nitzsch) Ehr. var. *subæqualis* Grun.

(Fig. 18)

Fritsch, F. E. and Rich, F., Contribution to Our Knowledge of the Fresh-water Algæ of Africa. Bacillariales (Diatoms) from Griqualand, West. *Trans. Roy. Soc. S. Africa*, Vol. 18, 1930, p. 97, fig. 2.

Valves like the type, but broadly rounded at the poles which are slightly constricted and narrowed. Striæ more than in the type.

Dimensions .. Length 380–427 μ
 Breadth 8–9 μ
 Striæ 12–13 in 10 μ

Habitat .. Fresh-water. Powai Lake. Fairly common.

19. *Synedra ulna* (Nitzsch) Ehr. var. *amphirhynchus* (Ehr.) Grun.

(Fig. 19)

Schönfeldt, Pascher's *Süsswasser-Flora*, Heft 10, 1913, p. 39; Hustedt, Fr., Pascher's *Süsswasser-Flora*, Heft 10, 1930, p. 154, fig. 167; Hustedt, Fr., Rabenhorst's *Kryptogamen-Flora*, Bd. VII, Teil 2, Lief 1-4, 1931-32, p. 200, fig. 691, A. e; Skvortzow, B. W., Diatoms from Khingan, North Manchuria, China, *Phil. Jour. Sci.*, Vol. 35, 1928, p. 39, pl. 1, fig. 21; Abdul Majeed, M., Fresh-water Algae of the Punjab, Part I. *Bacillariophyta* (Diatomeæ). *Punjab Univ. Publications*, Lahore, 1935, pl. 2, fig. 2; Venkataraman, G., A Systematic Account of Some South Indian Diatoms, *Proc. Ind. Acad. Sci.*, Vol. 10, No. 6, Sect. B, 1939, p. 308, figs. 28, 30-32.

Frustules solitary, in girdle view robust, elongated with constricted truncate apices. Valves straight, linear or slightly linear-lanceolate, constricted to form capitate ends. Striæ distinct. Pseudoraphe moderately wide, central area present.

Dimensions .. Length 130-150 μ
 Breadth 5.2-6 μ
 Striæ 7-10 in 10 μ

Habitat .. Fresh-water. Garden tank of Institute of Science, Bombay. Not common.

20. *Synedra rumpens* Kütz.

(Fig. 20)

Hustedt, Fr., Pascher's *Süsswasser-Flora*, Heft 10, 1930, p. 156, fig. 175; Hustedt, Fr., Rabenhorst's *Kryptogamen-Flora*, Bd. VII, Teil 2, Lief 1-4, 1931-32, p. 207, fig. 697 a, b; Abdul-Majeed, M., Fresh-water Algae of the Punjab, Part I. *Bacillariophyta* (Diatomeæ). *Punjab Univ. Publications*, Lahore, 1935, pl. 1, fig. 16; Skvortzow, B. W., Bottom Diatoms from Olhon Gate of Baikal Lake, Siberia, *Phil. Jour. Sci.*, Vol. 62, 1937, p. 293, pl. 5, figs. 6, 61.

Frustules usually bent or twisted in the middle. In girdle view narrowly linear with somewhat narrowed ends. Valves narrowly linear lanceolate, at the ends narrowed and capitate. Pseudoraphe linear and very narrow. Middle area without striæ. Striæ fine but distinct.

Dimensions .. Length 70-74 μ
 Breadth 3 μ
 Striæ 19-20 in 10 μ

Habitat .. Fresh-water. Powai Lake, streams and puddles near Kanheri Caves. Common.

21. *Synedra rumpens* Kütz. var. *familiaris* (Kütz.) Grun.

(Fig. 21)

Hustedt, Fr., Pascher's *Süsswasser-Flora*, Heft 10, 1930, p. 156, fig. 176; Hustedt, Fr., Rabenhorst's *Kryptogamen-Flora*, Bd. VII, Teil 2, Lief 1-4, 1931-32, p. 209, fig. 697 c.

Valves somewhat lanceolate and at the ends distinctly constricted and capitate. Also slightly constricted on both the sides of the central area.

Dimensions ... Length 48-49.5 μ
 Breadth 3.6 μ
 Striæ 16-18 in 10 μ

Habitat .. Fresh-water. Streams at Borivli and puddles near Kanheri Caves. Common.

22. *Synedra rumpens* Kütz. var. *fragilarioides* Grun.

(Fig. 22)

Hustedt, Fr., Pascher's *Süsswasser-Flora*, Heft 10, 1930, p. 156, fig. 178; Hustedt, Fr., Rabenhorst's *Kryptogamen-Flora*, Bd. VII, Teil 2, Lief 1-4, 1931-32, p. 209, fig. 697 e; Hustedt, Fr., *Archiv f. Hydrobiol. Suppl.* Bd. XV, 1938, p. 131, pl. 131, pl. 10, figs. 43-50.

Valves linear with narrow and capitate ends. The central area reaches the margins. Pseudoraphe linear and broad. Striæ fewer than in the type, strong and distantly placed.

Dimensions .. Length 39.6-42 μ
 Breadth 3.6 μ
 Striæ 10 in 10 μ

Habitat .. Fresh-water. Powai Lake and puddles near the Kanheri Caves. Common.

23. *Synedra rumpens* Kütz. var. *Meneghiniana* Grun.

(Fig. 23)

Hustedt, Fr., Pascher's *Süsswasser-Flora*, Heft 10, 1930, p. 156, fig. 179; Skvortzow, B. W., Diatoms from Ikeda Lake, Satsuma Province, Kiewisien Island, Nippon, *Phil. Jour. Sci.*, Vol. 62, 1937, p. 191, pl. 1, fig. 6; Sub-aerial Diatoms from Shanghai, Vol. 64, 1937, p. 443, pl. 2, fig. 6.

Valves linear lanceolate. Central area very distinct. Ends distinctly capitate. Striæ more distantly placed than in the type.

Dimensions .. Length 35-36.6 μ
 Breadth 3.2 μ
 Striæ 12-13 in 10 μ

Habitat .. Fresh-water. Streams at Borivli and Powai Lake. Common.

This form is slightly broader than *S. rumpens* var. *Meneghiniana* described by Hustedt.

II.	Sub-order	RAPHIDIOIDINEÆ
(1)	Family	EUNOTIACEÆ
(a)	Sub-family	Eunotioideæ
	Genus	<i>Eunotia</i> Ehrenberg, C. G., 1837.

24. *Eunotia prærupta* Ehr.

(Fig. 24)

Van Heurck, H., *Traité des Diatomées*, 1899, p. 302, pl. 9, fig. 376; Migula, W., *Kryptogamen-Flora*, Bd. II, Teil 1 a, p. 201, Taf. VII E, fig. 9; Schönfeldt, Pascher's *Süsswasser-Flora*, Heft. 10, 1913, p. 148, fig. 75; Gustav, L., *Die Algen*, 1914, p. 153, pl. 11, fig. 283; Hustedt, Fr., Pascher's *Süsswasser-Flora*, Heft 10, 1930, p. 174, fig. 211; Hustedt, Fr., Rabenhorst's *Kryptogamen-Flora*, Bd. VII, Teil 2, Lief 1-4, 1931-32, p. 280, fig. 747 a-c; Skvortzow, B. W., Diatoms from Kizaki Lake, Honshu Island, Nippon, *Phil. Jour. Sci.*, Vol. 61, 1936, p. 9, pl. 12, fig. 25; Bottom Diatoms from Olhon Gate of Baikal Lake, Siberia, *Phil. Jour. Sci.*, Vol. 62, 1937, p. 293, pl. 3, fig. 3.

Frustules in girdle view linear-rectangular. Valves arcuate with slightly concave ventral margin, somewhat parallel to the dorsal side. Dorsal wall at the ends slightly constricted. Ends flattened, rounded and bent backwards. Striæ coarse, more or less irregularly placed. Very small polar area is seen.

Dimensions .. Length 36-44 μ
 Breadth 8-9 μ
 Striæ 7-8 in 10 μ , sometimes 9-10.

Habitat .. Fresh-water. Powai Lake. Common.

25. *Eunotia prærupta* Ehr. var. *inflata* Grun.

(Fig. 25)

Van Heurck, H., *Traité des Diatomées*, 1899, p. 302, pl. 9, fig. 378; Hustedt, Fr., Pascher's *Süsswasser-Flora*, Heft 10, 1930, p. 174, fig. 212; Hustedt, Fr., Rabenhorst's *Kryptogamen-Flora*, Bd. VII, Teil 2, Lief 1-4, 1931-32, p. 280, fig. 747 f; Skvortzow, B. W., Bottom Diatoms from Olhon Gate of Baikal Lake, Siberia, *Phil. Jour. Sci.*, Vol. 62, 1937, p. 293, pl. 4, figs. 10-11; Diatoms from a Peaty Bog in Lianchiho River Valley, Eastern Siberia, *Phil. Jour. Sci.*, Vol. 66, 1938, p. 161, pl. 3, fig. 15.

Valves arcuate with the dorsal side highly convex and ventral side slightly concave. Striæ irregularly placed. Forms usually smaller than the type.

Dimensions .. Length 30.6-36 μ
 Breadth 9-9.6 μ
 Striæ 8-9 in 10 μ

Habitat .. Fresh-water. Streams at Borivli and Powai Lake. Not very common.

26. *Eunotia prærupta* Ehr. var. *muscolica* Petersen f. *major* f. nov.

(Fig. 26)

Valvæ lineares, ad medium ventris paullum concavæ. Dorsum fere rectum in medio, decrescens atque constrictum ad apices oblique truncatis. Longit. 45–46 μ , latit. 10 μ , striæ 10 in 10 μ .

Valves linear, slightly concave on the ventral side towards the middle. Dorsal side almost straight in the middle, narrowed and constricted at the ends. Apices obliquely truncate.

Dimensions .. Length 45–46 μ
 Breadth 10 μ
 Striæ 10 in 10 μ

Habitat .. Fresh-water. Streams at Borivli. Rare.

This form differs from Petersen's *E. prærupta* Ehr. var. *muscolica* Petersen (Petersen, J. B., *Bot. Iceland*, Vol. 2, 1932, p. 325, fig. 3) in having obliquely truncate apices, and larger dimensions. It is 45–46 μ long, 10 μ broad, while Petersen's form is only 26.4 μ long and 6–8 μ broad. However, in general outline and nature and number of striæ it agrees with *E. prærupta* Ehr. var. *muscolica* Petersen. Hence, it is regarded as a new form.

27. *Eunotia arcus* Ehr.

(Fig. 27)

Smith, W., *Syn. Brit. Diat.*, Vol. 1, 1853, pl. 2, fig. 15; Hassall, *Hist. Brit. Fresh-water Algæ*, Vols. 1 and 2, 1857, pl. 35, fig. 5; Van Heurck, *Traité des Diatomées*, 1899, p. 296, pl. 9, fig. 362; Migula, W., *Kryptogamen-Flora*, Bd. II, Teil 1 a, pl. 199, Taf. II, fig. 4; Gustav, L., *Die Algen*, 1914, p. 148, pl. 10, fig. 279; Hustedt, Fr., Pascher's *Süßwasser-Flora*, Heft 10, 1930, p. 175, fig. 216; Hustedt, Fr., Rabenhorst's *Kryptogamen-Flora*, Bd. VII, Teil 2, Lief 1–4, 1931–32, p. 282, fig. 748 a–c; Skvortzow, B. W., Diatoms from a Peaty Bog in Lianchiho River Valley, Eastern Siberia, *Phil. Jour. Sci.*, Vol. 66, 1938, p. 161, pl. 2, fig. 20; Abdul-Majeed, M., *Fresh-water Algæ of the Panjab*, Part I. Bacillariophyta (Diatomeæ). *Panjab Univ. Publications*, Lahore, 1935.

Frustules delicate. Ventral side slightly concave, dorsal side arcuate and strongly constricted at the ends, which are somewhat capitate and flatly rounded. Very small area is seen at the ends. Striæ coarse.

Dimensions .. Length 39.6–48 μ
 Breadth 6–7 μ
 Striæ 11–12 in 10 μ

Habitat .. Fresh-water. Streams at Borivli, Powai Lake.
 Not common.

28. *Eunotia arcus* Ehr. var. *uncinata* Grun.

(Fig. 28)

Van Heurck, *Traité des Diatomées*, 1899, p. 296, pl. 9, fig. 364; Migula, W., *Kryptogamen-Flora*, Bd. II, Teil 1 a, p. 200, Taf. XI, fig. 8; Hustedt, Fr., *Pascher's Süßwasser-Flora*, Heft 10, 1930, p. 175, fig. 218; Hustedt, Fr., *Rabenhorst's Kryptogamen-Flora*, Bd. VII, Teil 1, Lief 1-4, 1931-32, p. 282, fig. 748 e.

Valves arcuate. In all respects like the type, except that the ends are obliquely truncate and slightly constricted on the dorsal side. Striæ rather closely placed.

Dimensions .. Length 81-84 μ
 Breadth 10.5 μ
 Striæ 12-14 in 10 μ .

Habitat .. Fresh-water. Streams at Borivli. Common.

29. *Eunotia fallax* A. Cleve var. *gracillima* Krasske

(Fig. 29)

Hustedt, Fr., *Pascher's Süßwasser-Flora*, Heft 10, 1930, p. 178, fig. 227; Hustedt, Fr., *Rabenhorst's Kryptogamen-Flora*, Bd. VII, Teil 2, Lief 1-4, 1931-32, p. 288, fig. 753 a; Hustedt, Fr., *Archiv f. Hydrobiol.*, Suppl. Bd. XV, 1938, p. 131, pl. 10, figs. 19-21.

Frustules in girdle view, narrow rectangular. Valves delicate, linear and slightly arcuate. The side walls are somewhat parallel and tapering at the poles. Ends slightly constricted on the dorsal side, but not capitate. Ends backwardly bent. Raphe not well developed. Striæ distinct.

Dimensions .. Length 40.5-42 μ
 Breadth 3.6 μ
 Striæ 12 in 10 μ

Habitat .. Fresh-water. Ponds at Goregaon and Jogeswari.
 Not very common.

30. *Eunotia fallax* A. Cleve var. *gracillima* Krasske f. *densistriata* f. nov.

(Fig. 30)

Valvæ delicatæ, lineares et paullum arcuatæ, dorsum distincte convexum venter concavus, apices ad dorsum constricti, decrescentes et producti, verum not capitata. Raphe parvum evoluta. Striæ tenuissimæ et proxime eviter se dispositæ.

Valves delicate, linear and slightly arcuate. Dorsal side distinctly convex, ventral side concave. Poles constricted on the dorsal side, tapering and produced, but not capitate. Raphe poorly developed. Striæ very fine and very closely placed.

Dimensions .. Length 58μ
 Breadth 3.6μ
 Striæ 16–17 in 10μ

This form differs from *E. fallax* A. Cleve var. *gracillima* Krasske as its ends are produced. Moreover the sides are not parallel for the greater portion of their length as in the type. The striæ also are very fine and very closely placed. Hence it is regarded as a new form.

31. *Eunotia valida* Hust. var. *ambigua* var. nov.

(Fig. 31)

Valvæ lineares, margine ventrali distincte concavo; dorsum arcuatum, ad medium cum ventre fere parallelum. Apices attenuati, valde constricti, etiam capitati atque rotundati. Striæ crassæ et longe inter se dispositæ. Ratio longitudinis ad latitudinem est 1: 13–16. Longit. $90\text{--}111\mu$; latit $7.5\text{--}9\mu$; Striæ 8–9 in 10μ .

Valves linear, ventral margin distinctly concave, dorsal side arched, almost parallel to the ventral side in the middle. Ends narrowed and strongly constricted, also capitate and rounded. Striæ coarse and distantly placed. Proportion of length: breadth = 1; 13–16.

Dimensions .. Length $90\text{--}111\mu$
 Breadth $7.5\text{--}9\mu$
 Striæ 8–9 in 10μ

Habitat .. Fresh-water. Streams and pools at Borivli.
 Not very common.

This form at first sight resembles Hustedt's *E. pectinalis* (Kutz.) Rabh. (Hustedt, in A. Pascher's *Süßwasser-Fl.*, p. 180, fig. 237, 1930) in general outline. The ventral side here, however, is more concave and not at all gibbous, the dorsal side is distinctly arched and parallel to the ventral side and not flat as in the type. Moreover, the ends are suddenly constricted on the dorsal side, rounded, capitate and slightly bent backwards. It differs from *E. valida* Hust. (Hust. in A. Pascher's *Süßwasser-Fl.*, 1930, p. 178, fig. 229) as the constriction at the ends on the dorsal side is very conspicuous. It is also slightly broader and the striæ are not as closely placed as in *E. valida*. Of these two species it is nearer *E. valida* and is therefore, regarded as a new variety of *E. valida* Hust.

32. *Eunotia valida* Hust. var. *ambigua* var. nov. f. *Borivliana* f. nov.

(Fig. 32)

Valvæ lineares, latere ventrali valde concavo, dorso arcuato et fere parallelo cum ventre. Apices valde attenuati neque capitati ut in typo *E. valida* Hust. var. *ambigua* var. nov. Striæ crassæ et distincte positæ. Longit. 118μ ; Latit. 7.2μ ; Striæ 8–9 in 10μ .



H. P. GANDHI, M. Sc.

FIGS. 24-49 b.—Fig. 24. *Eunotia praeputa* Ehr., $\times 630$. Fig. 25. *Eunotia praeputa* Ehr. var. *inflata* Grun., $\times 630$. Fig. 26. *Eunotia praeputa* Ehr. var. *musculicola* Petersen f. *major* f. nov., $\times 630$. Fig. 27. *Eunotia arcus* Ehr., $\times 630$. Fig. 28. *Eunotia arcus* Ehr. var. *uncinata* Grun., $\times 630$. Fig. 29. *Eunotia fallax* A. Cleve var. *gracillima* Krasske, $\times 630$. Fig. 30. *Eunotia fallax* A. Cleve var. *gracillima* Krasske f. *densestriata* f. nov., $\times 630$. Fig. 31. *Eunotia valida* Hust. var. *ambigua* var. nov., $\times 630$. Fig. 32. *Eunotia valida* Hust. var. *ambigua* var. nov. f. *Borivliana* f. nov., $\times 630$. Fig. 33. *Eunotia pectinalis* (Kütz.) Rabh. var. *gibbulosus* Venkataraman, $\times 630$. Fig. 34. *Eunotia pectinalis* (Kütz.) Rabh. var.

undulata (Ralfs) Rabh., $\times 630$. Fig. 35. *Eunotia pseudopectinalis* Hust. f. *robusta* f. nov., $\times 700$. Fig. 36. *Eunotia veneris* (Kütz.) O. Müll., $\times 630$. Fig. 37. *Eunotia lunaris* (Ehr.) Grun., 700. Fig. 38. *Eunotia lunaris* (Ehr.) Grun. var. *subarcuata* (Naëg.) Grun., $\times 630$. Fig. 39. *Eunotia alpina* (Naëg.) Hust., $\times 630$. Fig. 40. *Eunotia monodon* Ehr., $\times 630$. Fig. 41. *Cocconeis placentula* Ehr. rapheless valve, $\times 630$. Fig. 41 a. *Cocconeis placentula* Ehr., view of valve with raphe, $\times 630$. Fig. 42. *Cocconeis placentula* Ehr. var. *euglypta* (Ehr.) Cleve, $\times 630$. Fig. 43. *Cocconeis placentula* Ehr. var. *lineata* (Ehr.) Cleve, $\times 630$. Fig. 44 a. *Cocconeis scutellum* Ehr., view of valve with raphe, $\times 630$. Fig. 44 b. *Cocconeis scutellum* Ehr., view of rapheless valve, $\times 630$. Fig. 45 a. *Eucocconeis lapponica* Hust. f. *rostrata* f. nov., view of valve with raphe, $\times 630$. Fig. 45 b. *Eucocconeis lapponica* Hust. f. *rostrata* f. nov., view of rapheless valve, $\times 630$. Fig. 46 a. *Achnanthes hungarica* Grun., view of valve with raphe, $\times 630$. Fig. 46 b. *Achnanthes hungarica* Grun., view of rapheless valve, $\times 630$. Fig. 47. *Achnanthes andicola* (Cleve) Hust., view of valve with raphe, $\times 630$. Fig. 47 a. *Achnanthes andicola* (Cleve) Hust., view of rapheless valve, $\times 630$. Fig. 48 a. *Achnanthes andicola* (Cleve) Hust. var. *elongata* var. nov., view of valve with raphe, $\times 630$. Fig. 48 b. *Achnanthes andicola* (Cleve) Hust. var. *elongata* var. nov., view of rapheless valve, $\times 630$. Fig. 49 a. *Achnanthes exigua* Grun., view of valve with raphe, $\times 630$. Fig. 49 b. *Achnanthes exigua* Grun., view of rapheless valve, $\times 630$.

Valves linear, ventral side strongly concave, dorsal side arched, almost parallel to the ventral side. Ends strongly narrowed and not capitate as in the type *E. valida* Hust. var. *ambigua* var. nov. Striæ coarse and distantly placed.

Dimensions .. Length 118 μ
 Breadth 7.2 μ
 Striæ 8–9 in 10 μ

Habitat .. Fresh-water. Streams at Borivli. Not common.

This form resembles *E. valida* Hust. var. *ambigua* var. nov., in all respects except that the ends are not capitate but produced. The ventral margin at the ends is slightly bent backward. The form is also slightly narrower. Hence, it is regarded as a new form of *E. valida* Hust. var. *ambigua* var. nov.

33. *Eunotia pectinalis* (Kütz.) Rabh. var. *gibbulosus* Venkataraman (Fig. 33)

Venkataraman, G., A Systematic Account of Some South Indian Diatoms, *Proc. Ind. Acad. Sci.*, Vol. 10, No. 6, Sect. B, 1939, p. 309, fig. 22.

Valves linear, dorsal side arcuate and distinctly tumid in the middle. Ventral side slightly concave and gibbous in the middle. Slight constriction present near the poles on the dorsal side. Ends broadly rounded. Striæ strong and distinct, but irregularly placed.

Dimensions .. Length 125–134.5 μ
 Breadth 8–9 μ
 Striæ .. 7–10 in 10 μ

Habitat .. Fresh-water. Streams at Borivli, Powai Lake.
 Not common.

This form is slightly bigger than the one described by Venkataraman.

34. *Eunotia pectinalis* (Kütz.) Rabh. var. *undulata* (Ralfs) Rabh.
(Fig. 34)

Smith, W., *Syn. Brit. Diat.*, Vol. 1, 1853, pl. 33, fig. 281; Hassall, *Hist. Brit. Fresh-Water Algæ*, Vols. 1 and 2, 1857, pl. XCV, figs. *b*, *c*, *d*; Van Heurck, *Traité des Diatomées*, 1899, p. 301, pl. 9, fig. 320; Hustedt, Fr., Pascher's *Süsswasser-Flora*, Heft 10, 1930, p. 182, fig. 240; Hustedt, Fr., Rabenhorst's *Kryptogamen-Flora*, Bd. VII, Teil 2, Lief 1-4, 1931-32, pl. 298, figs. 763 *f*, *g*, *i*.

Frustules rectangular in girdle view. Valves linear. Dorsal side arcuate with distinct undulations. Ventral side gibbous in the middle. Ends rounded as in the type, raphe seen at the poles. Striæ strong and irregular, closely placed near the poles.

Dimensions .. Length 85-90 μ
Breadth 8-9 μ
Striæ 9-12 in 10 μ

Habitat .. Fresh-water. Powai Lake. Common.

35. *Eunotia pseudopectinalis* Hust. f. *robusta* f. nov.

(Fig. 35)

Valvæ lineares, aliquantum arcuatæ, lateribus fere parallelis. Dorsum leviter constrictum ad apices plane rotundatos. Margo ventralis tenui pseudoraphide ornatus. Apices nodulis bene evolutis præditi. Longit. 142 μ ; latit. 12 μ ; striæ 7-8 in 10 μ .

Valves linear, slightly arcuate with almost parallel sides. Dorsal side slightly constricted at the ends which are flatly-rounded. Ventral margin has faint pseudoraphe. Ends have well-developed nodules.

Dimensions .. Length 142 μ
Breadth 12 μ
Striæ 7-8 in 10 μ

Habitat .. Fresh-water. Streams at Borivli. Rare.

This form agrees with *E. pseudopectinalis* Hust. (Hustedt, in Rabenhorst's *Kryptogamen-Flora*, Bd. VII, Teil 2, Lief 1-4, 1931-32, p. 314., fig. 779) in general outline, polar nodules and narrowed ends. However, it differs from the type in having greater breadth and distantly placed striæ which are also strong. Hence, it is regarded as a new form of *Eunotia pseudopectinalis* Hust.

36. *Eunotia veneris* (Kütz.) O. Mull.

(Fig. 36)

Migula, W., *Kryptogamen-Flora*, Bd. II, Teil 1 *a*, p. 301, fig. 766; Hustedt, Fr., Pascher's *Süsswasser-Flora*, Heft 10, 1930, p. 182, fig. 245; Hustedt, Fr., Rabenhorst's *Kryptogamen-Flora*, Bd. VII, Teil 2, Lief 1-4, 1931-32, p. 300, fig. 766; Skvortzow, B. W., *Diatoms from*

a Peaty Bog in Lianchiho River Valley, Eastern Siberia, *Phil. Jour. Sci.*, Vol. 66, 1938, p. 161, pl. 1, fig. 31.

Frustules rectangular and slightly rhombic in girdle view. Valve semi-lanceolate, with almost straight ventral margin. Dorsal margin strongly arched. Ends not constricted but acutely rounded. End nodules seen on the ventral margin. Striæ fine and very closely placed at the ends.

Dimensions .. Length 23–29 μ
 Breadth 4 μ
 Striæ 14–16 in 10 μ

Habitat .. Fresh-water. Pond at Jogeswari. Common.

37. *Eunotia lunaris* (Ehr.) Grun.

(Fig. 37)

Van Heurck, *Traité des Diatomées*, 1899, p. 303, pl. 9, fig. 384; Migula, W., *Kryptogamen-Flora*, Bd. II, Teil 1 a, p. 203, Taf. VII E, figs. 3, 12; Schönfeldt, Pascher's *Süßwasser-Flora*, Heft 10, 1913, p. 51, fig. 91; Hustedt, Fr., Pascher's *Süßwasser-Flora*, Heft 10, 1930, p. 183, fig. 249; Hustedt, Fr. Rabenhorst's *Kryptogamen-Flora*, Bd. VII, Teil 2, Lief 1–4, 1931–32, p. 303, fig. 748; Skvortzow, B. W., Diatoms from Khingan, North Manchuria, China, *Phil. Jour. Sci.*, Vol. 35, 1928, p. 39, pl. 2, figs. 4–5; Diatoms from Poyang Lake, Hunan, China, *Phil. Jour. Sci.*, Vol. 57, 1935, p. 465, pl. 1, fig. 15; Biswas, K., Common Diatoms of the Loktak Lake, Manipur, Assam, *Jour. Roy. Asiat. Soc. of Bengal*, Vol. II, No. 2, 1936, p. 174, pl. 5, fig. 9.

Frustules narrow, linear in girdle view. Valves very delicate and arcuate, usually strongly arched with almost parallel margins. Ends slightly narrowed, rounded and delicate. End nodules small. Raphe not well developed. Striæ fine.

Dimensions .. Length 81–156 μ
 Breadth 4–5 μ
 Striæ 13–17 in 10 μ

Habitat .. Fresh-water. Streams at Borivli, pools at Jogeswari. Common.

38. *Eunotia lunaris* (Ehr.) Grun. var. *subarcuata* (Naëg.) Grun.

(Fig. 38)

Van Heurck, *Traité des Diatomées*, 1899, p. 304, pl. 9, fig. 899; Hustedt, Fr. Pascher's *Süßwasser-Flora*, Heft 10, 1930, p. 185, fig. 251.

Frustules small, dorsal side of the valve arcuate, ventral side slightly concave. Ends rounded. Striæ like the type.

Dimensions .. Length 18–20 μ
 Breadth 3.4 μ
 Striæ 13–15 in 10 μ

Habitat .. Fresh-water. Powai Lake. Rare.

39. *Eunotia alpina* (Naëg.) Hust.

(Fig. 39)

Hustedt, Fr., Pascher's *Süsswasser-Flora*, Heft 10, 1930, p. 185, fig. 252; Hustedt, Fr., Rabenhorst's *Kryptogamen-Flora*, Bd. VII, Teil 2, Lief 1-4, 1931-32, p. 304, fig. 770.

Frustules linear in girdle view. Valves long and narrow, well arched, gradually tapering from the middle towards the ends. Ends acutely rounded, slightly bent backwards. End nodules clear. Raphe not well developed. Striæ fine.

Dimensions .. Length 63-80 μ
 Breadth 3 μ
 Striæ 15 in 10 μ

Habitat .. Fresh-water. Powai Lake, pools at Jogeswari, puddles at Wadala and other places. Common.

This form agrees with the type except that it is slightly broader.

40. *Eunotia monodon* Ehr.

(Fig. 40)

Smith, W., *Syn. Brit. Diat.*, Vol. I, 1853, p. 16, pl. 2, fig. 16; Schönfeldt, Pascher's *Süsswasser-Flora*, Heft 10, 1913, p. 45, fig. 73; Hustedt, Fr., Pascher's *Süsswasser-Flora*, Heft 10, 1930, p. 185, fig. 254; Hustedt, Fr., Rabenhorst's *Kryptogamen-Flora*, Bd. VII, Teil 2, Lief 1-4, 1931-32, p. 305, fig. 772 a, b; Venkataraman, G., A Systematic Account of Some South Indian Diatoms, *Proc. Ind. Acad. Sci.*, Vol. 10, No. 6, Sect. B, 1939, p. 310, fig. 40.

Valves arcuate. Dorsal side very strongly convex and gradually narrowing towards the ends which are rounded. Ventral margin slightly concave. Pseudoraphe present near the ventral margin, distinct. Striæ coarse, more closely placed near the poles.

Dimensions .. Length 68-75 μ
 Breadth 10.8-12 μ
 Striæ 8-10 in 10 μ

Habitat .. Fresh-water. Streams at Borivli, Powai Lake. Common.

III. Suborder MONORAPHIDINEÆ

(1) Family ACHNANTHACEÆ

(a) Subfamily Cocconeoidæ

Genus *Cocconeis* Ehrenberg, C. G., 1838.41. *Cocconeis placentula* Ehr.

(Figs. 41, 41 a)

Smith, W., *Syn. Brit. Diat.*, Vol. I, 1853, pl. 3, fig. 32; Van Heurck, *Traité des Diatomées*, 1899, p. 288, pl. 8, fig. 341; Schönfeldt, Pascher's

Süsswasser-Flora, Heft 10, 1913, p. 58, fig. 106; Gustav, L., *Die Algen*, 1914, p. 153, pl. 11, fig. 293; Hustedt, Fr., Pascher's *Süsswasser-Flora*, Heft 10, 1930, p. 189, fig. 260; Hustedt, Fr., Rabenhorst's *Kryptogamen-Flora*, Bd. VII, Teil 2, Lief 1-4, 1931-32, p. 347, figs. 802 *a, b*; Skvortzow, B. W., Diatoms from Calcutta, India, *Phil. Jour. Sci.*, Vol. 58, 1935, p. 179; Sub-aerial Diatoms from Shanghlai, Vol. 64, 1937, pl. 2, fig. 10; Notes on the Algal-flora of New Zealand. II. Fresh Water Algæ from Napier, Vol. 67, 1938, p. 411, pl. 1; Abdul-Majeed, M., Fresh-water Algæ of the Punjab, Part I. Bacillariophyta (Diatomeæ). *Panjab University Publications*, Lahore, 1935, p. 17, pl. 2, figs. 14-15.

Valves elliptical in outline. Valve with raphe has radial, fine but distinctly punctate striæ which are crossed by a hyaline band near the margin. Some distantly-placed prominent markings are also observed near the margin as in the type. Raphe straight, thread-like with closely placed central pores. Terminal fissures distant from the poles. Axial area very narrow, central area small, elliptical. Rapheless valve with striæ distinctly punctate. Pseudoraphe narrow and linear.

Dimensions .. Length 25-27 μ
 Breadth 16-17 μ
 Striæ 23 in 10 μ

Habitat .. Fresh-water. Streams at Borivli, Powai Lake.
 Common.

42. *Cocconeis placentula* Ehr. var. *euglypta* (Ehr.) Cleve.

(Fig. 42)

Hustedt, Fr., Pascher's *Süsswasser-Flora*, Heft 10, 1930, p. 190, fig. 261; Hustedt, Fr., Rabenhorst's *Kryptogamen-Flora*, Bd. VII, Teil 2, Lief 1-4, 1931-32, p. 349, fig. 802 *c*; Skvortzow, B. W., Diatoms from Poyang Lake, Hunan, China, *Phil. Jour. Sci.*, Vol. 57, 1935, p. 465, pl. 1, fig. 20; Diatoms from the Philippine, I. Diatoms from drinking water, Balara, Rizal Province, Vol. 64, 1937, p. 287, pl. 1, figs. 35, 37; Iyengar, M. O. P. and Subrahmanyam, R., Fossil Diatoms from the Karewa Beds of Kashmir, *Proc. of the National Acad. Sci. India*, Vol. 13, Pt. 4, 1943, p. 229, figs. 7, 8; Venkataraman, G., A Systematic Account of Some South Indian Diatoms, *Proc. Ind. Acad. Sci.*, Vol. 10, No. 6, Sect. B, 1939, p. 311, figs. 64-66.

Valves linear-elliptical to elliptical, both the valves similar in outline but dissimilar in structure. Valve with raphe has distinct central nodule, striæ radial, finely punctate. Margin of the valve separated from the central part by a hyaline band outside which is a striated ring. Rapheless valve with narrow linear pseudoraphe. Striæ not finely punctate but linear, so that a large number of longitudinal bands appear as if crossing the striæ.

- Dimensions .. Length 37–40 μ
 Breadth 16–17 μ
 Striæ on the valve with raphe 23 in 10 μ
 Striæ on the raphe-less valve 18 in 10 μ
- Habitat .. Fresh-water. Streams at Borivli, Powai Lake.
 Not common.

43. *Cocconeis placentula* Ehr. var. *lineata* (Ehr.) Cleve.

(Fig. 43)

Van Heurck, *Traité des Diatomées*, 1899, p. 288, pl. 8, fig. 344; Hustedt, Fr., Pascher's *Süßwasser-Flora*, Heft 10, 1930, p. 190, fig. 262; Hustedt, Fr., Rabenhorst's *Kryptogamen-Flora*, Bd. VII, Teil 2, Lief 1–4, 1931–32, p. 348, fig. 802 d; Skvortzow, B. W., Diatoms from Kizaki Lake, Honshu Island, Nippon, *Phil. Jour. Sci.*, Vol. 61, 1936, p. 9, pl. 2, fig. 5; Abdul-Majeed, M., Fresh-water Algæ of the Panjab, Part I. Bacillariophyta (Diatomeæ). *Panjab University Publications*, Lahore, 1935, p. 18, pl. 1, figs. 17, 18.

Valves elliptical. Rapheless valve with radial clearly punctate striæ, but near the margin puncta become irregular. On the valve with raphe hyaline band present as in the type, near the margin. Central nodule small.

- Dimensions .. Length 25–28 μ
 Breadth 15–15.6 μ
 Striæ 18–20 in 10 μ .
- Habitat .. Fresh-water. Garden tank, Institute of Science,
 Powai Lake. Not common.

44. *Cocconeis scutellum* Ehr.

(Figs. 44 a, b)

Smith, W., *Syn. Brit. Diat.*, Vol. I, 1853, pl. 3, fig. 34; Van Heurck, *Traité des Diatomées*, 1899, p. 287, pl. 8, fig. 338; Migula, W., *Kryptogamen-Flora*, Bd. II, Teil 1 a, p. 206, Taf. VII E, fig. 6; Hustedt, Fr., Pascher's *Süßwasser-Flora*, Heft 10, 1930, p. 191, fig. 267; Hustedt, Fr., Rabenhorst's *Kryptogamen-Flora*, Bd. VII, Teil 2, Lief 1–4, 1931–32, p. 338, fig. 790.

Frustules flat. Valves elliptical to broadly elliptical in outline. Valve with raphe has radial, slightly curved and finely punctate striæ. Puncta near the margin in groups, separated by a hyaline band. A second hyaline band present, parallel to the one near the margin. Raphe thin and straight, terminal fissures distant from the ends. Central nodule very small. Rapheless valve with large squarish puncta arranged in radial rows. On the margin a double row of small puncta present in small compartments. Pseudoraphe narrowly lanceolate.

- Dimensions .. Length 25–37 μ
 Breadth 20–25 μ
 Striæ on valve with raphe 7–8 in 10 μ
 Puncta 10 in 10 μ
 Striæ on raphe-less valve 7 in 10 μ
 Puncta 7–8 in 10 μ .
- Habitat .. Brackish-water. Mahim creek. Common.
- (b) Subfamily Achnanthoideæ
 Genus *Eucocconeis* Cleve

45. *Eucocconeis lapponica* Hust. f. *rostrata* f. nov.

(Fig. 45 a, b)

Valvæ lineares, ellipticæ, apicibus late rotundatis et rostratis. Valva inferior raphide prædita est. Raphe recta, paullum ad apices curvata. Striæ aliquantum radiales. Area axialis angusta, area centralis parva et rotunda. Valva superior pseudoraphide atque maiore area centrali vel rectangulari vel quadrata prædita. Longit. 14–16 μ ; latit. 5.4 μ ; striæ 30 in 10 μ .

Valves linear elliptical with broadly rounded rostrate ends. Lower valve with raphe. Raphe straight, slightly curved at the poles. Striæ slightly radial. Axial area narrow, central area small and rounded. Upper valve with pseudoraphe and a bigger rectangular or square central area.

- Dimensions .. Length 14–16 μ
 Breadth 5.4 μ
 Striæ indistinct nearly 30 in 10 μ .

Habitat .. Fresh-water. Pools at Jogeswari. Rare.

This form differs from *Eucocconeis lapponica* Hust. (Hust. in Pascher's *Süßwasser-Flora*, Heft 10, 1930, p. 194, fig. 272) in having suddenly contracted, broadly rostrate ends. The valves also are more linear. In the number of striæ, central areas, obliquely placed raphe and pseudoraphe it resembles *E. lapponica* Hust. It is, therefore, regarded as a new form of *E. lapponica* Hust.

- Genus *Achnanthes* Bory, 1822.
 Subgenus *Microneis*

46. *Achnanthes hungarica* Grun.

(Fig. 46 a, b)

Van Heurck, *Traité des Diatomées*, 1899, p. 280, pl. 8, fig. 328; Migula, W., *Kryptogamen-Flora*, Bd. II, Teil 1 a, Taf. VII E, p. 212, fig. 14; Schönfeldt, Pascher's *Süßwasser-Flora*, Heft 10, 1913, p. 56, fig. 101; Hustedt, Fr., Pascher's *Süßwasser-Flora*, Heft 10, 1930, p. 201, fig. 283; Hustedt, Fr., Rabenhorst's *Kryptogamen-Flora*, Bd. VII, Teil 2, Lief 1–4, 1931–32, p. 383, fig. 829; Skvortzow, B. W.,

Diatoms from Poyang Lake, Hunan, China, *Phil. Jour. Sci.*; Vol. 57, 1935, p. 465, pl. 1, figs. 16–19; Abdul-Majeed, M., Fresh-water Algæ of the Panjab, Part I. Bacillariophyta (Diatomeæ). *Panjab University Publications*, Lahore, 1935, p. 18, pl. 2, figs. 7–8.

Valves broadly linear with wedge-shaped ends. Valve with raphe has thread-like raphe, bent towards one side at the poles. Axial area narrow, extended to the margins in the middle. Central area one-sided, on the opposite side short striæ are present. Striæ slightly radial. Rapheless valve has narrow pseudoraphe. Central area very small, due to shortening of the middle striæ. Striæ perpendicular to the middle line in the centre and radial at the ends.

Dimensions .. Length 20–25 μ
 Breadth 7.2–7.7 μ
 Striæ on the valve with raphe 20–21 in 10 μ
 Striæ on the rapheless valve 22 in 10 μ .

Habitat .. Fresh-water. Streams at Borivli, pond at Andheri, garden tank of Institute of Science. Common.

47. *Achnanthes andicola* (Cleve) Hust.

(Fig. 47, 47 a) ..

Hustedt, Fr., Pascher's *Süsswasser-Flora*, Heft 10, 1930, p. 201, fig. 234; Hustedt, Fr., Rabenhorst's *Kryptogamen-Flora*, Bd. VII, Teil 2, Lief 1–4, 1931–32, p. 384, fig. 830.

Valves linear-lanceolate in outline, gibbous in the middle. Ends obtusely rounded. Valve with raphe has straight raphe with distinct central pores. Terminal fissures not reaching the poles. Axial area narrow and linear. Central area broad, reaching the side walls. Polar area distended. Striæ strong, usually perpendicular to the middle line or slightly radial. Rapheless valve with narrow pseudoraphe and linear central area reaching the sides. Striæ strong, very slightly radial or perpendicular to the middle line. Polar areas absent in rapheless valve.

Dimensions .. Length 45–50 μ
 Breadth 10–10.8 μ
 Striæ 15 in 10 μ

Habitat .. Fresh-water. Streams at Borivli. Rare.

48. *Achnanthes andicola* (Cleve) Hust. var. *elongata* var. nov.

(Fig. 48 a, b)

Valvæ lanceolatæ vel leviter lineari-lanceolatæ, in medio gibbosæ. Apices rotundati. Valva raphide prædita rectam raphidem poris centralibus distinctis habet. Pori terminales longius a polis sunt. Area axialis angusta, linearis. Area centralis lata, sed usque ad margines non extensa. Parvæ striæ in area centrali apparent. Striæ fortes,

in medio aliquantum radiales, ad apices perpendiculares. Valva non raphide prædita pseudoraphide lineari ornata, et area centrali usque ad margines extensa. Longit, 90–92 μ ; latit, 13 μ ; striæ 10 in 10 μ .

Valves lanceolate or slightly linear-lanceolate in outline, gibbous in the middle. Ends rounded. Valve with raphe has straight raphe with distinct central pores. Terminal pores distant from the poles. Axial area narrow, linear. Central area broad not reaching the margins. Small striæ are present in the central area. Striæ strong and slightly radial in the middle and perpendicular at the poles. Rapheless valve with linear pseudoraphe and central area reaching the sides.

Dimensions .. Length 90–92 μ
Breadth 13 μ
Striæ 10 in 10 μ .

Habitat .. Fresh-water. Streams at Borivli. Rare.

This form differs from the type *A. andicola* (Cleve) Hust. (Hust. in A. Pascher's *Süsswasser-Flora*, Heft 10, 1930, p. 201, fig. 234; in Rabenhorst's *Kryptogamen-Flora*, Bd. VII, Teil 2, Lief 1–4, 1931–32, p. 384, fig. 830), in having elongated, and strongly striated valves. The Striæ are more distantly placed than in the type. Moreover, the central area has short striæ on the valve with raphe which are absent in the type. Hence, it is regarded as a new variety of *A. andicola* (Cleve) Hust.

49. *Achnanthes exigua* Grun.

(Fig. 49 a, b)

Migula, W., *Kryptogamen-Flora*, Bd. II, Teil, 1 a, p. 212, Taf. VII F, fig. 5; Hustedt, Fr., Pascher's *Süsswasser-Flora*, Heft 10, 1930, p. 201, fig. 286; Hustedt, Fr., Rabenhorst's *Kryptogamen-Flora*, Bd. VII, Teil 2, Lief 1–4, 1931–32, p. 386, fig. 832 a, b; Skvortzow, B. W., Diatoms from Calcutta, India, *Phil. Jour. Sci.*, Vol. 58, 1935, p. 179, pl. 1, fig. 2; Diatoms from Kizaki Lake, Honshu Island, Nippon, Vol. 61, 1936, p. 9, pl. 7, fig. 16.

Valves rectangular-elliptical to almost quadrate in the middle portion, constricted at the ends which are rostrate. Valve with raphe has thin straight raphe. Axial area narrow and central area linear reaching the margins. Striæ distinct and slightly radial. Rapheless valve with linear-lanceolate pseudoraphe and central area absent.

Dimensions .. Length 14·4–16 μ
Breadth 5·4–6 μ
Striæ 22 in 10 μ

Habitat .. Fresh-water. Streams at Borivli and garden tank of Institute of Science. Not common.

50. *Achnanthes exigua* Grun. var. *heterovalvata* Krasske

(Fig. 50 a, b)

Hustedt, Fr., Pascher's *Süsswasser-Flora*, Heft 10, 1930, p. 202, fig. 288; Hustedt, Fr., Rabenhorst's *Kryptogamen-Flora*, Bd. VII, Teil 2, Lief 1-4, 1931-32, p. 387, figs. 832, e, f.

Like the type in shape and other characteristics. The only difference is that the striæ on the valve with raphe are more than on the rapheless valve. Poles are somewhat capitate and truncate. Central area in the rapheless valve reaches the side walls.

Dimensions .. Length 12.5-15 μ
 Breadth 5.4-6 μ
 Striæ on the valve with raphe 30 in 10 μ
 Striæ on the rapheless valve 22 in 10 μ

Habitat .. Fresh-water. Streams at Borivli, garden tank of Institute of Science. Fairly common.

51. *Achnanthes lanceolata* Bréb.

(Fig. 51 a, b)

Van Heurck, *Traité des Diatomées*, 1899, p. 282, pl. 8, fig. 336; Migula, W., *Kryptogamen-Flora*, Bd. II, Teil 1 a, p. 212, Taf X, fig. 13; Hustedt, Fr., Pascher's *Süsswasser-Flora*, Heft 10, 1930, p. 207, fig. 306 a; Hustedt, Fr., Rabenhorst's *Kryptogamen-Flora*, Bd. VII, Teil 2, Lief 1-4, 1931-32, p. 408, figs. 863 a-b; Geitler, L., *Der Formwechsel der pinneten Diatomeen (Kieselalgen)*, *Archiv f. Protistenkunde*, Heft I, Vol. 78, 1932, p. 100, figs. 59-65; Skvortzow, B. W., *Diatoms from Kizaki Lake, Honshu Island, Nippon*, *Phil. Jour. Sci.*, Vol. 61, 1936, p. 9, pl. 2, figs. 11-12; Bottom Diatoms from Olhon Gate of Baikal Lake, Siberia, Vol. 62, p. 293, pl. 5, fig. 13.

Valves elliptical-lanceolate, somewhat dilated in the middle. Ends broadly rounded and flat. Raphe thread-like. Axial area narrow, linear. Central area broad. Striæ strong, radial. Rapheless valve with lanceolate pseudoraphe. In the centre on one side, a horse-shoe-shaped marking is clearly seen.

Dimensions .. Length 12.6-15 μ
 Breadth 5-5.6 μ
 Striæ 12-13 in 10 μ

Habitat .. Fresh-water. Garden tank of Institute of Science
 Common. Only smaller forms were seen.

52. *Achnanthes lanceolata* Bréb. var. *elliptica* Cleve

(Fig. 52 a, b)

Hustedt, Fr., Pascher's *Süsswasser-Flora*, Heft 10, 1930, p. 208, fig. 306 c; Hustedt, Fr., Rabenhorst's *Kryptogamen-Flora*, Bd. VII, Teil 2, Lief 1-4, 1931-32, p. 410, figs. 863 n, o; Skvortzow, B. W.,

Diatoms from Kizaki Lake, Honshu Island, Nippon, *Phil. Jour. Sci.*, Vol. 61, 1936, p. 9, pl. 2, fig. 29; Bottom Diatoms from Olhon Gate of Baikal Lake, Siberia, Vol. 62, 1937, p. 293, pl. 5, fig. 14.

The valves here are elliptical in outline. Striæ fine and radial. Horse-shoe-shaped marking present on one side of the central area.

Dimensions .. Length 9–13 μ
 Breadth 4–5.6 μ
 Striæ 14–15 in 10 μ

Habitat .. Fresh-water. Garden tank of Institute of Science. Common.

53. *Achnanthes lanceolata* Bréb. var. *tenuis* var. nov.

(Fig. 53 a, b)

Valvæ lineares, ad medium dilatatae. Apices late rotundati et plauti. Valva raphide instructa rectam raphidem habet. Area axialis angusta, linearis, ad medium ita latior ut aream centralem efficiat. Striæ radiales. Valva sine ulla raphide, pseudoraphide instructa, ad medium lanceolata. Striæ equinæ soleæ figuræ in medio ad alterum latus videtur. longit. 23–24 μ ; Latit. 4.5 μ ; striæ 13–14 in 10 μ .

Valves linear, dilated in the middle. Ends broadly rounded and flat. Valve with raphe has straight raphe, axial area narrow, linear, widening in the middle to form the central area. Striæ radial. Rapheless valve with pseudoraphe lanceolate in the middle. A horse-shoe-shaped marking is seen in the centre to one side.

Dimensions .. Length 23–24 μ
 Breadth 4.5 μ
 Striæ 13–14 in 10 μ

Habitat .. Fresh-water. Garden tank of Institute of Science. Rare.

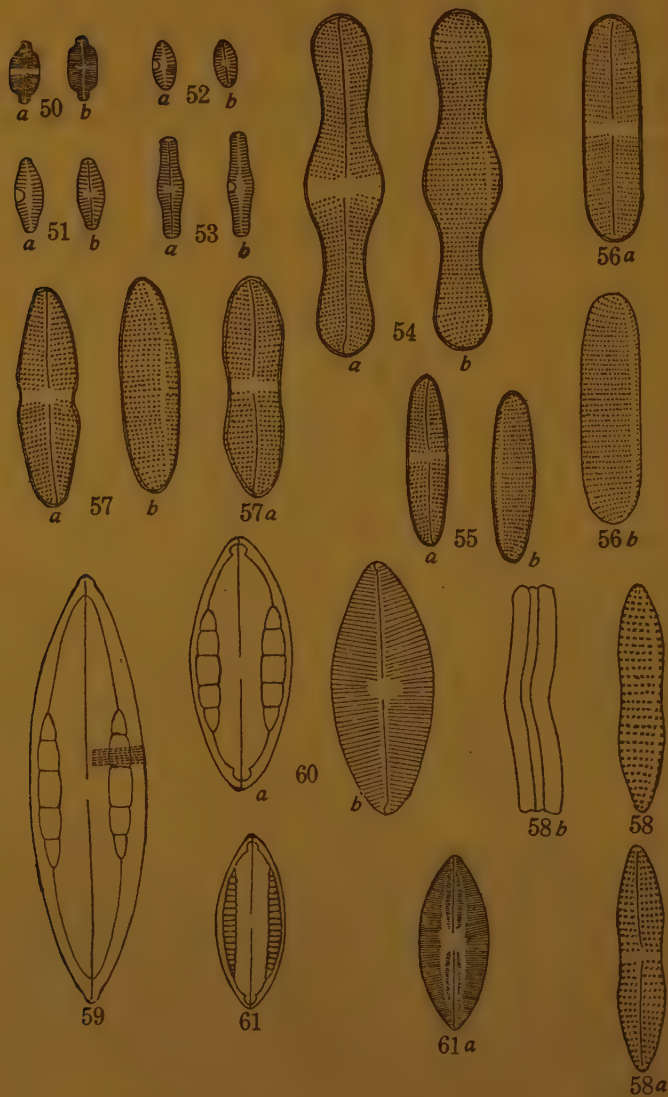
This form is linear and is more slender and more delicate than the type. It resembles *A. Grimmei* Krasske, (Hust. in Pascher's *Süßwasser-Flora*, Heft 10, 1930, p. 205, fig. 302) in shape and dimensions, but differs in having a distinct horse-shoe-shaped marking on the rapheless valve, on one side of the central area. The striæ are also coarser than in *A. Grimmei*. As this form only differs from the *A. lanceolata* Bréb. in having linear valves and broadly truncate ends, it is regarded as a new variety of *A. lanceolata* Bréb.

Subgenus *Achnanthidium* (Kütz.) Heiberg, 1863.

54. *Achnanthes inflata* Kütz.

(Fig. 54 a, b)

Hustedt, Fr., Pascher's *Süßwasser-Flora*, Heft 10, 1930, p. 209, fig. 307; Hustedt, Fr., Rabenhorst's *Kryptogamen-Flora*, Bd. VII, Teil 2, Lief 1–4, 1931–32, p. 421, fig. 873; Skvortzow, B. W., *Alpine*



H. P. GANDHI, M.Sc.

FIGS. 50 a-61 a.—Fig. 50 a. *Achnanthes exigua* Grun. var. *heterovalvata* Krasske, view of valve with raphe, $\times 630$. Fig. 50 b. *Achnanthes exigua* Grun. var. *heterovalvata* Krasske, view of rapheless valve, $\times 630$. Fig. 51 a. *Achnanthes lanceolata* Bréb., view of rapheless valve, $\times 630$. Fig. 51 b. *Achnanthes lanceolata* Bréb., view of valve with raphe, $\times 630$. Fig. 52 a. *Achnanthes lanceolata* Bréb. var. *elliptica* Cleve, view of valve with raphe, $\times 630$. Fig. 52 b. *Achnanthes lanceolata* Bréb. var. *elliptica* Cleve, view of valve without raphe, $\times 630$. Fig. 53 a. *Achnanthes lanceolata* Bréb. var. *tenuis* var. nov., view of valve with raphe, $\times 630$.

Fig. 53 *b*. *Achnanthes lanceolata* Bréb. var. *tenuis* var. nov., view of rapheless valve, $\times 630$. Fig. 54 *a*. *Achnanthes inflata* Kütz., view of valve with raphe, $\times 630$. Fig. 54 *b*. *Achnanthes inflata* Kütz., view of rapheless valve, $\times 630$. Fig. 55 *a*. *Achnanthes coarctata* Bréb. var. *elliptica* Krasske, view of valve with raphe, $\times 630$. Fig. 55 *b*. *Achnanthes coarctata* Bréb. var. *elliptica* Krasske, view of rapheless valve, $\times 630$. Fig. 56 *a*. *Achnanthes coarctata* Bréb. var. *parallela* Venkataraman, view of valve with raphe, $\times 630$. Fig. 56 *b*. *Achnanthes coarctata* Bréb. var. *parallela* Venkataraman, view of rapheless valve, $\times 630$. Fig. 57 *a*. *Achnanthes brevipes* Agardh var. *intermedia* (Kütz.) Cleve, view of valve with raphe, $\times 630$. Fig. 57 *b*. *Achnanthes brevipes* Agardh var. *intermedia* (Kütz.) Cleve, view of rapheless valve, $\times 630$. Fig. 58. *Achnanthes longipes* Agardh, view of valve without raphe, $\times 630$. Fig. 58 *a*. *Achnanthes longipes* Agardh, view of valve with raphe, $\times 630$. Fig. 58 *b*. *Achnanthes longipes* Agardh, frustule in girdle view, $\times 630$. Fig. 59. *Mastogloia amoyensis* Voigt var. *robusta* var. nov., $\times 1,000$. Fig. 60 *a*. *Mastogloia exigua* Lewis f. *brevirostris* Venkataraman, valve showing loculi, $\times 1,000$. Fig. 60 *b*. *Mastogloia exigua* Lewis f. *brevirostris* Venkataraman, valve showing striations, $\times 1,000$. Fig. 61. *Mastogloia dolosa* Venkataraman var. *ambigua* var. nov., valve showing loculi, $\times 630$. Fig. 61 *a*. *Mastogloia dolosa* Venkataraman var. *ambigua* var. nov., valve showing striations, $\times 630$.

Diatoms from Fukein Province, South China, *Phil. Jour. Sci.*, Vol. 41, 1930, p. 39, pl. 1; Mills, Fr., Some Diatoms from Warri, South Nigeria, *Jour. Roy. Microsc. Soc.*, London, Vol. LII, Ser. III, 1932, p. 383, pl. II, figs. 4–7; Venkataraman, G., A Systematic Account of Some South Indian Diatoms, *Proc. Ind. Acad. Sci.*, Vol. 10, No. 6, Sect. B, 1939, p. 314, figs. 52, 54, 67.

Frustules in girdle view linear, bent in the middle. Valves linear, dilated in the middle. Ends somewhat capitate with broadly rounded poles. Valve with raphe has strong and straight raphe. Axial area narrow, central area stauroid. Striæ radial, punctate. Puncta moniliform. Rapheless valve with narrow, excentric and distinct pseudo-raphe. Striæ are in the middle perpendicular to the middle line, at the poles radial and curved, punctate; puncta moniliform.

Dimensions .. Length 76–80 μ
 Breadth 16.6 μ
 Striæ 8–9 in 10 μ

Habitat .. Fresh-water. Streams at Borivli. Rare. This form is slightly larger than the type.

55. *Achnanthes coarctata* Bréb. var. *elliptica* Krasske.

(Fig. 55 *a*, *b*)

Hustedt, Fr., Pascher's *Süsswasser-Flora*, Heft 10, 1930, p. 210, fig. 308 *b*, Hustedt, Fr., Rabenhorst's *Kryptogamen-Flora*, Bd. VII, Teil 2, Lief 1–4, 1931–32, p. 420, fig. 872.

Valves somewhat elliptical, in the middle not constricted like the type. Poles slightly narrowed and broadly rounded. Valve with raphe has straight and strong raphe. Axial area narrow but distinct, central area broad, reaching the side walls. Striæ are slightly radial with small, moniliform puncta. Rapheless valve with strongly excentric pseudoraphe. Striæ punctate.

Dimensions .. Length 37·6–50 μ
 Breadth 9–10·8 μ
 Striæ 8–11 in 10 μ
 Puncta 10 in 10 μ .

Habitat .. Fresh-water. Streams at Borivli. Rare. Brackish-water. Mahim creek. Common.

56. *Achnanthes coarctata* Bréb. var. *parallela* Venkataraman

(Fig. 56 a, b)

Venkataraman, G., A Systematic Account of Some South Indian Diatoms, *Proc. Ind. Acad. Sci.*, Vol. 10, No. 6, Sect. B, 1939, p. 314, figs. 46, 47, 48.

Frustules in girdle view, linear and bent unilaterally. Valves linear with broad rounded ends. Walls almost parallel in the middle. Raphe straight and coarser in the middle. Axial area broad, reaching the margins, rectangular. Striæ distinctly punctate and radial. Pseudoraphe excentric on the rapheless valve.

Dimensions .. Length 41–50 μ
 Breadth 10 μ
 Striæ 10–12 in 10 μ

Habitat .. Fresh-water. Streams at Borivli. Fairly common.

57. *Achnanthes brevipes* Agardh var. *intermedia* (Kütz.) Cleve

(Fig. 57 a, b)

Schönfeldt, Pascher's *Süßwasser-Flora*, Heft 10, 1913, p. 58; Hustedt, Fr., Pascher's *Süßwasser-Flora*, Heft 10, 1930, p. 210, fig. 310; Hustedt, Fr., Rabenhorst's *Kryptogamen-Flora*, Bd. VII, Teil 2, Lief 1–4, 1931–32, p. 425, figs. 877 c, d; Venkataraman, G., A Systematic Account of Some South Indian Diatoms, *Proc. Ind. Acad. Sci.*, Vol. 10, No. 6, Sect. B, p. 315, figs. 55, 58, 59, 60, 63.

Valves linear with rounded ends, constricted in the middle on the side of valve with raphe, while the rapheless valve is not constricted in the middle. Raphe straight, slightly excentric. Central area stauroid. Pseudoraphe strongly excentric on the rapheless valve. Rows of puncta more radial at the poles. Puncta are large and distinct.

Dimensions .. Length 47–50 μ
 Breadth 10·8 μ
 Striæ 9–10 in 10 μ

Habitat .. Fresh-water. Streams at Borivli. Not common.

58. *Achnanthes longipes* Agardh

(Fig. 58, 58 a, b)

Van Heurck, H., *Traité des Diatomées*, 1899, p. 229, pl. 8, fig. 323; Migula, W., *Kryptogamen-Flora*, Bd. II, Teil 1 a, p. 210, Taf. X, fig. 10; Gustav, L., *Die Algen*, 1914, p. 258, pl. 11, fig. 290; Karsten, G., Engler and Prantl's *Die Natürlichen, Pflanzenfamilien*, Bd. II, 1928, p. 269, fig. 357 b; Hustedt, Fr., Rabenhorst's *Kryptogamen-Flora*, Bd. VII, Teil 2, Lief 1-4, 1931-32, p. 427, fig. 878; Skvortzow, B. W., Marine Diatoms from the Kanazawa Oyster Experimental Station of Japan, *Phil. Jour. Sci.*, Vol. 47, 1932, p. 119, pl. 2, figs. 10, 11.

Valves in girdle view linear elliptical, distinctly constricted in the middle with wedge-shaped narrow rounded ends. Valve with raphe has distinct, axial raphe. Axial area narrow, central area somewhat smaller, sometimes extended to margins of the valves forming a narrow stauros. Striæ almost perpendicular to the middle line. On rapheless valve excentric pseudoraphe present. Striæ punctate. Puncta are distinctly linear, arranged in pairs. At the ends striæ are radial.

Dimensions .. Length 48-52.4 μ
 Breadth 9-10.5 μ
 Striæ 6-7 in 10 μ
 Puncta 9 in 10 μ

Habitat .. Brackish-water. Mahim creek. Not common.

IV. Suborder BIRAPHIDINEÆ

(1) Family NAVICULACEÆ

(a) Subfamily Naviculoideæ

Genus *Mastogloia* Thwaites, 1856.

59. *Mastogloia amoyensis* Voigt var. *robusta* var. nov.

(Fig. 59)

Valvæ lanceolatæ, apicibus paullum constrictis atque acute rotundatis. Area axialis angusta. Area centralis aliquantum parva. Raphe tenuis et recta. Striæ parallelæ, punctatæ. Puncta elongata. Loculi in medio ampliores, minores ad apices, longius ab apicibus deficientes. Longit. 58.4-60 μ ; latit. 12.5 μ ; striæ, 16-20 in 10 μ .

Valves lanceolate with slightly constricted and acutely rounded ends. Axial area narrow. Central area fairly small. Raphe thin and straight. Striæ parallel, punctate. Puncta elongated. Loculi larger in the middle and smaller at the ends, ending at a distance from the poles.

Dimensions .. Length 58.4-60 μ
 Breadth 12.5 μ
 Striæ 16-10 in 10 μ
 Length of the larger loculi 3.6-5 μ
 Length of the smaller loculii 2.5 μ

Habitat .. Fresh-water. Pools and streams at Borivli.
 Common.

This form resembles *M. amoyensis* Voigt (Voigt M., Contribution to the knowledge of the Diatom Genus *Mastogloia*, *Jour. Roy. Microsc. Soc. London*, Vol. 62, 1942, Ser. III, p. 1, pl. 1, fig. 1) in outline, number of loculi and their configuration. However, due to robustness of the valves, the larger dimensions, the distantly placed linear and distinctly punctate striae and the greater distance of the loculi from the poles as compared to the type, the present form is considered as a new variety of *M. amoyensis* Voigt.

60. *Mastogloia exigua* Lewis f. *brevirostris* Venkataraman

(Fig. 60 a, b)

Venkataraman, G., A Systematic Account of Some South Indian Diatoms, *Proc. Ind. Acad. Sci.*, Vol. 10, No. 6, Sect. B, 1939, p. 317, figs. 44-45.

Valves elliptical, with broadly rounded ends. Raphe straight with slightly bent terminal fissures. Axial area narrow, central area somewhat square. Striae radial and indistinctly punctate. Loculi five in number, bigger in the middle and smaller at the ends. The two longitudinal septa bands curve suddenly inwards and out again before joining together near the ends. Thus their outline appears capitate at the ends.

Dimensions .. Length 30.6-34 μ
 Breadth 12.6-13 μ
 Striae 18-20 in 10 μ
 Length of larger loculi 3-4.5 μ
 Length of smaller loculi 2-2.5 μ

Habitat .. Fresh-water. Streams at Borivli. Common.

This form resembles *M. exigua* Lewis f. *brevirostris* Venkataraman in all details, except that the breadth is more and the striae are slightly less in number.

61. *Mastogloia dolosa* Venkataraman var. *ambigua* var. nov.

(Fig. 61, 61 σ)

Valvae ellipticae lanceolatae, apicibus rotundis. Area axialis angusta: area centralis ampla, rectangularis, duabus notis hyalinis longitudinalibus litterae H similibus ornatae quae in apicibus convergere et convenire videntur. Striae pallum radiales, tenuiter punctatae. Loculi plures in medio ampliores, paulo minores in apicibus. Septa longitudinalia primo intus, tum extus curvantur tandem haud longe ab apicibus conveniunt. Longit., 37-38.5 μ ; latit. 14.4 μ ; striae 20-24 in 10 μ .

Valves elliptical lanceolate with rounded ends. Axial area narrow, central area big, rectangular with two hyaline H-shaped longitudinal markings which seem to converge and meet at the ends. Striae slightly radial and finely punctate. Loculi numerous, bigger in the middle, slightly smaller at the ends. The longitudinal septa bend inwards and out again before joining near the ends.

Dimensions ..	Length	37–38·5 μ
	Breadth	14·4 μ
	Striæ	20–24 in 10 μ
	Breadth of loculi	2 μ
	No. of loculi	4–5 in 10 μ
Habitat ..	Fresh-water. Streams at Borivli. Not very common.	

This form resembles *M. dolosa* Venkataraman (Venkataraman, G., A Systematic Account of Some South Indian Diatoms, *Proc. Ind. Acad. Sci.*, Vol. 10, No. 6, Sect. B, 1939, p. 316, fig. 49) in its shape and in having H-shaped hyaline furrows in the middle, but the ends are narrowly rounded and not subrostrate as in the type. The end portion of the longitudinal septa is distinctly capitate, as in *M. exigua* Lewis f. *brevirostris* Venk. (*Venk. op. cit.*, p. 317, figs. 44, 45). Hence this form is between *M. dolosa* Venk. and *M. exigua* Lewis f. *brevirostris* Venk. resembling the former in shape and hyaline H-shaped furrows and the latter in the capitate end portion of the longitudinal septa. As it shows greater resemblance to *M. dolosa* Venk. it is considered as a new variety of *M. dolosa* Venk.

SOME NOTEWORTHY PLANTS FROM EAST NEPAL

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(Received for publication on January 24, 1952)

IN 1948 the author accompanied an expeditionary party to East Nepal, where he collected specimens of about 425 species of plants. In this lot are included a few specimens, the occurrence of which in Nepal is of considerable interest from the view-point of distribution of the species. Burkill in his 'Notes from a Journey to Nepal'* reports about the occurrence of three species in Nepal having an irregular distribution. To these three, the author adds five more. One of these is a new variety.

Hypericum hookerianum* W. & A. var. *linearis* Banerji. *Var. nov.

Folia generatim 4 cm. longa, $\frac{3}{4}$ cm. lata, sessilis, apice acutis, *inter alia* differt.

Nepal, from Tinpipli to Nepalthoke, about 1,000 m., Banerji 95 (TYPE in Herbarium, Indian Botanic Garden, Calcutta; Co-Type in Herbarium, Meerut College, Meerut).

At first the specimen showed some resemblance to a sheet named *Hypericum lanceolatum* Lam. in the Calcutta Herbarium. On closer examination the size of the sepals and the mature carpels was found to resemble those of *Hypericum hookerianum*, but the leaves were different. A specimen was sent to Kew, and I am indebted to Mr. J. Robert Sealy for the information that the plant does not agree exactly with the type of *H. hookerianum*, and that it might be a narrow-leaved variant. The leaves are generally 4 cm. long and $\frac{3}{4}$ cm. broad, sessile, apex acute.

***Desmodium renifolium* (Linn.) Schindler.**

[*Syn. D. reniforme* (Linn.) DC.]

Nepal, from Chainpur to Mialay, about 1,100 m., Banerji 558.

This species is previously reported from Kumaon, Western Peninsula, Assam and Burma.

***Androsace geraniifolia* Watt. var. *setosa* Kunth.**

Nepal, from Patala to Phaplu, about 2,700 m., Banerji 256.

* *Rec. Bot. Surv. India*, Vol. IV, No. 4, 86.

There is a wide difference between the specimen and original *A. geraniifolia*, but the material agrees with the specimens of this variety in the Kew Herbarium. ...

It is of interest that this variety has been collected from the Himalayas for the first time.

***Tylophora rotundifolia* Buch. Ham.**

Nepal, at Terthum about 1,300 m. Banerji 571.

The species has previously been collected from U.P. and South India.

***Tylophora wallichii* Hk. f.**

Nepal, from Dhupa to Wana, about 1,300 m. Banerji 541.

This has been previously collected and reported from Burma, Tenasserim and Malaya Peninsula.

The author is indebted to the authorities at Kew and Dr. S. K. Mukerji of Indian Botanic Garden, Calcutta, for furnishing the necessary information and checking the sheets. To Dr. V. Puri the author is immensely grateful for his interest and encouragement.

THE FOREST-COMPLEX OF PATHARIA HILL, SAGAR

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I. INTRODUCTION

THE forest cover of most of the hills of the North-Western part of Madhya Pradesh is of the Tropical Dry Deciduous type according to the classification of Champion (1936). It is a mixed forest in which it is difficult to find pure stands of the dominant trees for any considerable area. This may be possibly due to effective diversity in the habitat so that no single species possesses the ecological amplitude to cover the local range of environmental variations obtainable on the hills. In order to test this hypothesis the forest-complex of Patharia hill has been examined in some detail.

The hill rises up to a height of 300 feet on the eastern side of Sagar lake giving it a beautiful background as seen from the town. The ridges facing the lake are denuded of forest, but the top and the east facing slopes bear growth of varying density. The main ridge runs from the North to the South for about a mile and then curves towards the West for another mile before tapering into a spur extending for $2\frac{1}{2}$ miles to the South. The top forms a continuous long undulating plateau at an average altitude of 2,000 feet above the sea level. It is only 200-400 feet wide and bears a cart road all along. The sides of the hill are steep with an average gradient of one in four. They are frequently cut with deep gullies and ravines. Of the forested regions the South end of the ridge is called 'Rajababa', the middle part 'Gualipura' and in between a small flank extending to the east 'Saji Bhatar'. These are shown in the map (Fig. 1).

The average annual rainfall of Sagar is 48 inches. About 7 inches are received in June, 16 inches in July, 12 inches in August, 7-8 inches in September and over an inch in October. The average during the seven dry months works out to $2\frac{1}{2}$ inches.

The average monthly minimum and maximum temperatures are recorded as 52° F. and 77° F. in January, 78.5° F. and 105° F. in May and 74° F. and 83.5° F. in July (*vide Local Gazetteer*). The absolute minimum and maximum temperatures for several years are recorded as 39.1° F. in February and 114.4° F. in June. Frosts during the winter, however, are common in the valleys. Forest fire is occasional during the hot dry months of May and June.

The hills are built of Deccan Trap consisting of augite basalt, laid horizontally with localised intertrappean ash, clay and impure lime.

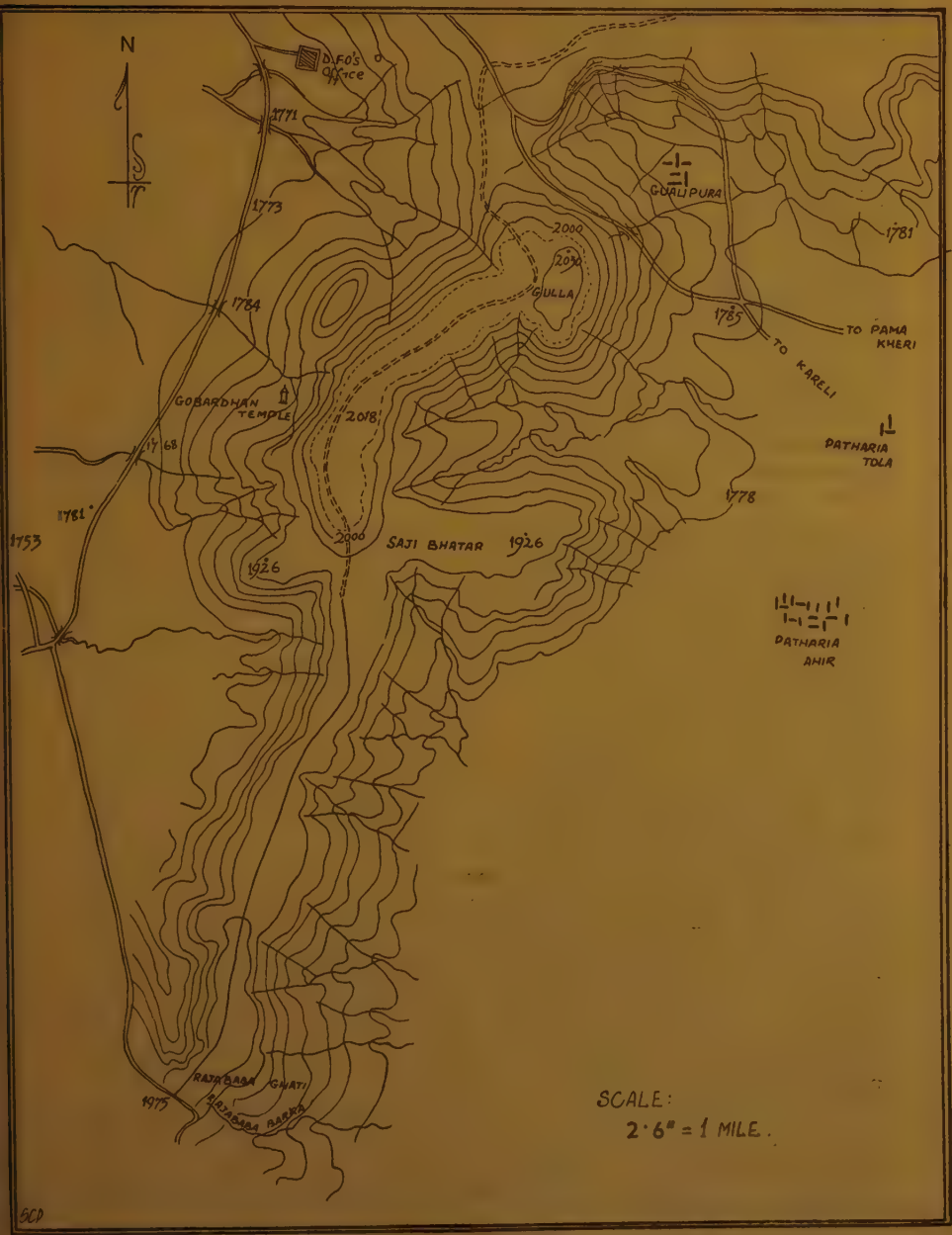


FIG. 1. A Contour Map of Patharia Hill

The rocks weather by exfoliation leaving black coloured boulders as outcrops. Erosion of the soil leaves the surface rough with pebbles and boulders of varying size.

The nature of the substratum with reference to the disposition of the rocks and physiographic factors is very important in following the distribution of the plants. The shallower deposits of clay and lime get leached out easily yielding place to stone and soil fillings in small patches on the plateau, but the parent material remains exposed on the slopes. The rains erode the surface and in consequence the top of the plateau generally remains rocky and bouldery with local deposits of sand; and the slopes being almost sections of the deposits, present a mosaic of bouldery, sandy, silted up and lime-rich areas. A large number of transect studies have invariably revealed a thin deposit of lateritic soil with lower pH values (5-6.5) at the top and a deeper calcareous (pH 6-8) balck silty soil towards the bottom. The latter is formed evidently by an admixture of finer particles enriched with salts of Ca, K, Na, etc., leached out from the top layers, together with decomposing litter. The soil however, accumulates locally on the gentler slopes due to rock or plant obstacles till it is sufficiently fastened to the substratum by root growth.

The most striking physiographic factor is intense gully erosion. Water falling on the top follows the gradient and pours down the slopes scouring narrow channels. The gullies so arising ramify across harder rocks and tend to converge on softer substrata. In doing so the possibilities of disappearance and reappearance of shallower channels in course of time are immense. As a result of the temporal physiographic activities fresh patterns of substrata may spatially arise due to out-cropping within the life-time of a tree species growing on the hill side. If the erosion is very rapid only such species as possess the capacity to regenerate from exposed roots can thrive. However, the fact remains that the substratum will largely consist of the exposed basalt, clay and lime deposits lying separated from each other save for shallower and fresher deposits on the surface.

Although the traps are laid horizontally, even a slight inclination of the rocks may keep underground water moving slowly from one side to the other giving rise to springs. Seepage water, in fact, can be found even during the dry months upto February at several places on the eastern slopes of the hills. The western flanks in consequence remain dry. This would largely explain the corresponding luxuriant growth and barrenness of the two sides of the hills. Though due to proximity of the town, the western side would also suffer from anthropogenic ravages.

Profound biotic effects are visible throughout the area. Lopping, cutting, browsing and grazing are some of the more important factors. Their indirect effect on the habitat, however, is more devastating to the forests. As soon as the annual balance of growth over loss trips in favour of the latter, erosion gets accelerated. Thus the intensity of the biotic factors has great bearing on the development of the substratum *via* the physiographic factors.

Thus it would seem that the edaphic, the physiographic and the biotic factors combine to create a dynamic system of habitats, through time and space, for the struggling forest growth on the hills.

II. METHODS OF STUDY

1. *Phytosociological characters*

The importance of phytosociological data was recognised from the very beginning of this study. The authors do not know of any detailed work of this nature on Indian forests. Potzer's (1946) emphasis on such data, Brown's (1941) work on Roan mountains and those of Richards (1939), Lucy Braun (1940 and 1942), Gates (1949) and Oosting (1948) were found to be sufficiently indicative of the methods.

A general survey of the forests revealed roughly seven types of tree-stands. In each of these species were recorded on line transects within a belt of about 10 feet, run across the contours for sufficiently long distances to cover the type. Frequency, abundance, dominance and sociability of each species were found out by the following calculations:—

(a) *Frequency*.—The sampling unit was taken to be a transect of 100 feet. Longer transects were consequently divided into separate units. Percentage occurrence of a species in the units was calculated in the usual manner and the frequency classes were expressed on 1-5 scale as given by Braun Blanquet (1932):—

Class 1 = Species occurring in 1- 20% of the transects

„ 2 =	„	„	21- 40%	„	„
„ 3 =	„	„	41- 60%	„	„
„ 4 =	„	„	61- 80%	„	„
„ 5 =	„	„	81-100%	„	„

(b) *Abundance*.—Numerical abundance was calculated from the tree counts on the following scale:—

Class 1 = Species forming 1- 3% of the trees

„ 2 =	„	„	4- 8%	„	„
„ 3 =	„	„	9- 15%	„	„
„ 4 =	„	„	16- 25%	„	„
„ 5 =	„	„	26-100%	„	„

(c) *Dominance*.—It was estimated according to spread of the crown of the species and expressed in five classes as given by Braun Blanquet (1932):—

Class 1 = with less than 5% cover of the ground

„ 2 =	covering	5- 25% of the ground		
„ 3 =	„	25- 50%	„	„
„ 4 =	„	50- 75%	„	„
„ 5 =	„	75-100%	„	„

(d) *Sociability*.—This also has been expressed in five degrees:—

Soc. 1	=	growing isolated
„ 2	=	„ in groups
„ 3	=	„ numbers
„ 4	=	„ little colonies
„ 5	=	„ large colonies

Records for the herb layer were taken in the months of October and November only.

2. *Soil characters*

Samples of soil were collected in cigarette tins and examined in the laboratory for the following:—

(a) *Carbonates*.—The degree of effervescence with dilute hydrochloric acid was arbitrarily noted.

(b) *Nitrates*.—They were noted by diphenylamine test as described by Misra (1946).

(c) *pH*.—This was determined colorimetrically.

(d) *Loss on ignition*.—This was estimated at a temperature of 600–700° C. in a muffle furnace.

III. THE FORESTS

1. *Tectona grandis*—*Anogeissus latifolia* type

The forest covers an area of about 380 acres extending from Raja Baba to Saji Bhatar (Fig. 1) mostly on the eastern slopes. It was reserved in 1890 according to forest office records. There has been a recent felling in 1932–38 and about 24 acres were burnt down in 1939. Hence most of the trees are young.

The soil on the top of the hill is red coloured gritty sand. It is seldom deeper than 6–9 inches and generally gets collected around boulders and trees on account of erosion. pH values range between 5 and 6. Down the slopes deposits of darker coloured soil covered with litter are locally met with. It is rich in organic matter, carbonates, nitrates and clay. It has a pH value between 6 and 7. Right at the foot of the hill black organic soil gets deposited deeply. Here it is generally cultivated. On the sides, however, fresh exposures of the traps and the intertrappean layers are often seen, especially along a number of gullies and ravines all across the area.

The forest is closed with a tree cover of 80–90%. The trees have attained a height of 25–40 feet. About 30% of them are *Tectona grandis* and 20% *Anogeissus latifolia*. There are at least 29 other species making up for the rest. Details of composition are shown in Table I.

Regeneration of the principal trees is quite good. Nevertheless saplings of *Terminalia tomentosa* and *Diospyros melanoxylon* are more abundant.

TABLE I

Composition of the *Tectona grandis* and *Anogeissus latifolia* type of forest

Species	F	A	D	S
1. <i>Diospyros melanoxylon</i> Roxb. ..	5	4	2	3
2. <i>Butea frondosa</i> Roxb. ..	5	4	1	2
3. <i>Terminalia tomentosa</i> W. and A. ..	5	3	2	2
4. <i>Flacourtia ramontchi</i> L'Herit. ..	5	4	2	2
5. <i>Anogeissus latifolia</i> Wall. ..	5	4	3	3
6. <i>Saccopetalum tomentosum</i> H.F. and T. ..	5	2	2	2
7. <i>Tectona grandis</i> Linn. ..	5	4	2	3
8. <i>Zizyphus xylopyra</i> Willd. ..	5	3	2	2
9. <i>Kydia calycina</i> Roxb. ..	5	2	2	4
10. <i>Stephegyne parviflora</i> Korth. ..	4	3	2	3
11. <i>Lagerstræmia parviflora</i> Roxb. ..	3	1	1	2
12. <i>Cassia fistula</i> Linn. ..	3	2	1	1
13. <i>Acacia catechu</i> Willd. ..	3	2	2	2
14. <i>A. leucophlæa</i> Willd. ..	3	2	2	1
15. <i>Dalbergia paniculata</i> Roxb. ..	3	2	1	1
16. <i>Gardenia latifolia</i> Ait. ..	3	2	2	1
17. <i>Phyllanthus emblica</i> Linn. ..	3	2	1	1
18. <i>Nyctanthes arbortristis</i> Linn. ..	3	2	2	4
19. <i>Careya arborea</i> Roxb. ..	3	2	1	1
20. <i>Holoptelea integrifolia</i> Planch. ..	2	2	1	2
21. <i>Bauhinia purpurea</i> Linn. ..	2	2	1	1
22. <i>Wrightia tinctoria</i> R.Br. ..	2	2	1	2
23. <i>Aegle marmelos</i> Correa ..	2	1	1	3
24. <i>Bridelia retusa</i> Spreng. ..	2	1	1	1
25. <i>Elæodendron glaucum</i> Pers. ..	1	1	1	1
26. <i>Buchnanian lanzan</i> Spreng. ..	1	1	1	1
27. <i>Ixora parviflora</i> Vahl. ..	1	1	1	1
28. <i>Bombax malabaricum</i> D.C. ..	1	1	1	1
29. <i>Albizia odoratissima</i> Benth. ..	1	1	1	1
30. <i>Ougeinia dalbergioides</i> Benth. ..	1	1	1	2

F = Frequency; A = Abundance; D = Dominance; S = Sociability.

The shrub layer is rather unevenly distributed, being denser on the slopes. *Carissa spinarum*, *Mimosa rubicaulis* and *Helicteris isora* form locally impregnable thickets. *Woodfordia floribunda* thrives best on calcareous soils or along the beds of channels.

Distribution of the herb layer depends chiefly upon the availability of sufficient light. Thus it may cover 80% of the ground in open or partly shaded areas, but be altogether absent in less than 2-3% of full light intensity as measured by an exposure meter at noon time. On

the slopes and eroded areas however, the thinness of the soil becomes the limiting factor and the cover may not grow to more than 5% of the area. The species are *Cassia tora* (a), *Spermacoce stricta* (f), *Sida rhomboidea* (f), *Heteropogon contortus* (f), *Indigofera* sp. (f), *Dichanthium annulatum* (f), and *Bothriochloa pertusa* (f). *Oplismenus* sp. (lf) and *Biophytum sensitivum* (o) occur in shade only.

2. *Anogeissus latifolia* and *Diospyros melanoxylon* type

It is a mature forest covering the steep slopes of the South-East side of Saji Bhatar (Fig. 1). Felling was done in 1895. It has not been much disturbed since then. *Anogeissus latifolia* and *Diospyros melanoxylon* form 35% and 20% of the trees respectively. Detailed composition of the forest is given in Table II.

TABLE II

Composition of the Anogeissus latifolia and Diospyros melanoxylon type of forest

Species	F	A	D	S
1. <i>Diospyros melanoxylon</i> Roxb. ..	5	4	3	3
2. <i>Butea frondosa</i> Roxb. ..	5	4	2	3
3. <i>Anogeissus latifolia</i> Wall. ..	5	4	3	3
4. <i>Lagerstræmia parviflora</i> Roxb. ..	4	4	2	2
5. <i>Terminalia tomentosa</i> W. and A. ..	4	2	2	2
6. <i>Saccopetalum tomentosum</i> H.F. and T. ..	4	3	2	2
7. <i>Odina wodier</i> Roxb. ..	3	2	2	1
8. <i>Elæodendron glaucum</i> Pers. ..	3	1	1	2
9. <i>Cassia fistula</i> Linn. ..	2	1	1	1
10. <i>Flacourtia ramontchi</i> L'Hert. ..	2	2	2	1
11. <i>Acacia catechu</i> Willd. ..	2	1	1	2
12. <i>Buchnanian lanzan</i> Spreng. ..	2	1	1	1
13. <i>Schleichera oleosa</i> (Lour.) Mer. ..	2	2	2	3
14. <i>Acacia leucophlæa</i> Willd. ..	1	1	1	1
15. <i>Holoptelea integrifolia</i> Planch ..	1	1	1	1
16. <i>Ixora parviflora</i> Vahl. ..	1	1	1	2
17. <i>Bridelia retusa</i> Spreng. ..	1	1	1	1

Regeneration of *Diospyros melanoxylon* is adequate and rapid. *Anogeissus latifolia* and *Saccopetalum tomentosum* saplings are becoming rarer. Recently grazing in this area has increased and this might be responsible for the changing composition.

Development of soil is poor on account of the steepness of the slope. It is generally a thin mantle of sand caught by the growth. However, grey coloured loam is often found on the lower terraces. pH values range from 6-7.8 and carbonates are high showing their addition from the releases from the outcropping of the intertrappean beds.

The shrub layer consists of *Carissa spinarum*, *Celastrus senegalensis* (a) and *Zizyphus ænopia* (f). *Anona squamosa* is plentiful along streams.

The herb layer is moderately developed on terraces with *Cassia tora* (a), *Spermocoe stricta* (f), *Sida veranæcifolia* (o), *Bothriochloa pertusa* (o) and *Oplismenus burmani* (o). However, on steeper slopes the growth is thinner and consists of *Evolvulus alsinoides* (f), *Tridax procumbens* (f), *Cassia tora* (f), *Indigofera cordifolia* (o), *Aristida* sp. (o) and *Iseilema anthephoroides* (r).

3. *Anogeissus latifolia*-*Diospyros melanoxylon* and *Terminalia tomentosa* Type

This is a dense forest (cover 80-100%) and is found on the eastern slopes of Saji Bhatar and in the valley formed by it and a curvature of the main ridge on the eastern face. It appears to be as old as the preceding type, but the substratum consists of terraces or gentle slopes with thick deposits of black silted loam. The average depth of the soil is about 8 inches-1 foot. It is rich in organic matter and covered with decomposing litter. Seepage water can be seen locally, making the soil boggy for a longer duration in the dry season. Average pH value of the soil is about 7.2.

TABLE III

Composition of Anogeissus latifolia, Diospyros melanoxylon and Terminalia tomentosa type of forest

Species		F	A	D	S
1.	<i>Diospyros melanoxylon</i> Roxb. ..	5	4	3	3
2.	<i>Terminalia tomentosa</i> W. and A. ..	5	4	3	2
3.	<i>Anogeissus latifolia</i> Wall. ..	5	4	3	3
4.	<i>Butea frondosa</i> Roxb. ..	4	2	2	2
5.	<i>Cassia fistula</i> Linn. ..	3	2	2	1
6.	<i>Odina wodier</i> Roxb. ..	3	3	2	1
7.	<i>Acacia leucophlæa</i> Willd. ..	3	1	1	1
8.	<i>Saccopetalum tomentosum</i> H.F. and T. ..	2	3	2	3
9.	<i>Bauhinia purpurea</i> Linn. ..	2	3	2	1
10.	<i>Wrightia tinctoria</i> R.Br. ..	2	2	2	3
11.	<i>Gardenia latifolia</i> Ait. ..	2	2	2	2
12.	<i>Schleichera oleosa</i> (Lour.) Mer. ..	2	2	2	3
13.	<i>Lagerstræmia parviflora</i> Roxb. ..	2	2	2	2
14.	<i>Flacourtia ramontchi</i> L'Herit. ..	2	1	1	1
15.	<i>Stephegyne parvifolia</i> Korth. ..	2	1	1	1
16.	<i>Acacia catechu</i> Willd. ..	2	1	1	2
17.	<i>Elæodendron glaucum</i> Pers. ..	2	1	1	1
18.	<i>Dalbergia paniculata</i> Roxb. ..	2	1	1	1
19.	<i>Buchnanania lanzan</i> Spreng. ..	2	1	1	1
20.	<i>Phyllanthus emblica</i> Linn. ..	2	1	1	1
21.	<i>Bassia latifolia</i> Roxb. ..	2	1	1	1

Anogeissus latifolia comprises 35% and *Diospyros melanoxylon* 25% of the trees. *Terminalia tomentosa* is codominant. This type differs from type 2 in having a preponderance of *Terminalia tomentosa* over *Lagerstræmia parviflora*. In fact the latter species is characteristic of sandy, badly eroded and poor soil and the former grows better on deeper and richer soils. Details of composition are given in Table III.

Regeneration of *Terminalia tomentosa* is progressive as seen from a larger number of saplings.

The shrubs are poor on account of the dense tree canopy. *Carissa spinarum* and *Ixora parviflora* are the only species commonly met with.

The herb layer shows an erratic distribution, presumably due to large variations in light intensity and water content of the soil. *Oplismenus* sp. (f), *Sida veranæcifolia* (o), *Desmodium* sp. (o) and *Impatiens balsamina* (o), all characteristic of shady situations, are often met with. The following species may form continuous cover in small patches: *Cassia tora* (f), *Oplismenus* sp. (f), *Iseilema antheophoroides* (o), *Setaria glauca* (o), *Bidens pilosa* (o), and *Biophytum sensitivum* (r).

4. *Aegle marmelos*-*Diospyros melanoxylon*-*Anogeissus latifolia* Type

This forest forms a small belt along the upper contours of the south face of Saji Bhatar. The three dominant species comprise 30, 25 and 20% of the trees. Details are given in Table IV.

TABLE IV

Composition of *Aegle Marmelos*, *Diospyros melanoxylon* and *Anogeissus latifolia* type of forest

Species	F	A	D	S
1. <i>Diospyros melanoxylon</i> Roxb. ..	5	4	3	3
2. <i>Anogeissus latifolia</i> Wall. ..	5	4	3	3
3. <i>Aegle marmelos</i> Correa. ..	5	4	3	3
4. <i>Butea frondosa</i> Roxb. ..	4	3	2	2
5. <i>Cassia fistula</i> Linn. ..	4	1	1	1
6. <i>Odina wodier</i> Roxb. ..	4	2	2	1
7. <i>Stephegyne parvifolia</i> Korth. ..	4	3	2	3
8. <i>Terminalia tomentosa</i> W. and A. ..	3	2	2	2
9. <i>Bauhinia purpurea</i> Linn. ..	3	3	2	2
10. <i>Lagerstræmia parviflora</i> Roxb. ..	3	1	1	1
11. <i>Flacourtia ramontchi</i> L. Herit. ..	3	1	1	1
12. <i>Saccopetalum tomentosum</i> H.F. and T. ..	3	1	2	2
13. <i>Wrightia tinctoria</i> R.Br. ..	3	1	2	2
14. <i>Gardenia latifolia</i> Ait. ..	2	2	2	2
15. <i>Tectona grandis</i> Linn. ..	2	2	2	2
16. <i>Acacia catechu</i> Willd. ..	3	1	2	2
17. <i>Elæodendron glaucum</i> Pers. ..	2	1	1	1
18. <i>Dalbergia paniculata</i> Roxb. ..	2	1	1	1

The soil is much eroded, but is grey coloured, heavier and rich in carbonates, apparently due to outcropping of extensive intertrappeans. The average pH value is about 7.3. The number of saplings of the dominant trees together with those of *Butea frondosa* is large, showing healthy regeneration of the forest.

The shrub layer is characterised by the calcicole *Woodfordia floribunda*. *Carissa spinarum* is also abundant.

The herb layer consists of the usual species as found in the other types except for the frequent occurrence of *Justicea diffusa*.

5. *Diospyros melanoxylon*-*Butea frondosa* Type

This is an open scrub jungle growing on most of the hills of the region. Its status is maintained by intense biotic factors under which most of the other tree saplings are eliminated. The flavour of their leaves is distasteful to the animals and hence the dominant trees of the type escape severe damage from the animals. However, the trees are low and gnarled on account of browsing, lopping and picking of the leaves. [The leaves of *Diospyros melanoxylon* are used in the manufacture of Biri (country cigarette) and those of *Butea frondosa* are used as trays for serving meals]. Nevertheless, the two trees provide 80% of the total canopy in this type.

Too frequent grazing exposes the land to erosion and hence the soil consists of sand and gravel. It is either lateritic with much of the sesquioxides remaining in the matrix or grey coloured due to addition of humus. The average pH value is about 6. However, calcareous deposits are also locally met with due to outcropping.

The terraces though more open are populated with mature trees and the slopes are largely covered with the lower forms. The composition of the tree layer is given in Table V.

TABLE V

Composition of the *Diospyros melanoxylon* and *Butea frondosa* type of forest

Species	F	A	D	S
1. <i>Diospyros melanoxylon</i> Roxb. ..	5	5	4	3
2. <i>Butea frondosa</i> Roxb. ..	5	5	3	3
3. <i>Flacourtia ramontchi</i> L'Herit. ..	5	2	2	2
4. <i>Lagerstræmia parviflora</i> Roxb. ..	4	2	2	2
5. <i>Acacia leucophlea</i> Willd. ..	4	2	2	1
6. <i>Cassia fistula</i> Linn. ..	3	2	2	1
7. <i>Holoptelea integrifolia</i> Planch. ..	3	2	2	2
8. <i>Stephegyne parvifolia</i> Korth. ..	2	1	1	2
9. <i>Bridelia retusa</i> Spreng. ..	2	1	1	1
10. <i>Terminalia tomentosa</i> W. and A. ..	1	1	1	2
11. <i>Bombax malabaricum</i> D.C. ..	1	1	1	2
12. <i>Zizyphus jujuba</i> Lamk. ..	1	1	1	1

The shrub layer consists of *Carissa spinarum* and *Flacourtia ramontchi* at most of the places, but on steeper slopes these are associated with *Celastrus senegalensis* (f), *Mimosa rubicaulis* (f), *Zizyphus ænopia* and *Zizyphus rotundifolia* (o). These form locally impregnable thickets.

The herb layer is very variable in density. On burning the spiny thickets a good grassland consisting of the following species may grow in course of time:—

Dichanthium annulatum (d), *Bothriochloa pertusa* (seasonally cd), *Iseilema antheophoroides* (ld), *Aristida cyanantha* (f), *Heteropogon contortus* (f), etc.

On poor and thin soil *Heteropogon contortus*, *Cymbopogon martini*, *Themeda caudata*, *Apluda mutica*, *Tridax procumbens*, etc., become more frequent.

In shaded and moist situations a characteristic community of *Setaria glauca*, *Oplismenus burmani*, *Paspalidium flavidum*, *Biophytum sensitivum*, *Euphorbia geniculata*, *Adiantum* sp., etc., may be found with varying frequency.

Seedlings of *Butea frondosa* and *Diospyros melanoxylon* are frequent in the grasslands. *Zizyphus rotundifolia* becomes locally dominant in lower regions where soil may get deposited rapidly.

6. *Anogeissus latifolia*–*Boswellia serrata*–*Diospyros melanoxylon*–*Butea frondosa* Type

A small patch of open forest differing from the preceding types in having a good percentage of *Boswellia serrata* is found in a valley opposite Gualipura (see map). It grows on steep slopes (50–70°) with thin greyish lateritic soil with a pH below 7. The hill sides remain sufficiently moist during the dry months with a seasonal stream running in the valley. Grazing is not severe on account of the steepness of the slope.

The commonest saplings are those of *Boswellia serrata*, *Butea frondosa*, *Diospyros melanoxylon* and *Anogeissus latifolia*.

Flacourtia ramontchi is frequent and the herb layer is characteristic of eroded areas. It consists of *Heteropogon contortus* (f), *Apluda mutica* (f), *Cymbopogon martini* (f), *Eragrostis elongata* (f), *Spermacoce stricta* (la), *Cassia pumila* (o) and *Justicea diffusa* (o).

Recent development of paper and match industries in the state has put *Boswellia serrata* trees much in demand, but its regeneration in the forests is reputed to be difficult. Hence the observation of a large number of saplings of this useful tree in the present type assumes much significance. The tree is no doubt found locally dominant and abundant in some of the old forests of Shahgarh at about 40 miles to the north. Its saplings, however are rare in the closed communities though regeneration of the other associates in those forests is common. Hence it is surmised that *Boswellia serrata* can regenerate more easily in open communities situated on steep slopes with thin, moist and sandy soil derived from the trap.

7. Riverain Types

It has been observed that gullies are frequently cut on the hill sides by the storm water and that those keep on changing the course. They become as dry as the terraces in the post-monsoon seasons. But down the slopes on the eastern faces of the ridge some of them are fed by spring water for varying periods. The stream beds so formed throughout the areas described, bear a characteristic community which deserves separate treatment.

Anogeissus latifolia, *Diospyros melanoxylon* and *Butea frondosa* amongst the trees and *Woodfordia floribunda* and *Anona squamosa* amongst the shrubs seem to be the most characteristic species of the drier tracts. *Terminalia glabra*, *Buchnanian lanzan*, *Eugenia* spp. and *Ficus* sp. together with those named above on the other hand, abound in the moister regions.

IV. INTERRELATIONS BETWEEN THE FOREST TYPES

The seven types of the forest stands described in this study seem to be interrelated floristically. Sociological values for the first five types are given in Table VI.

It will be seen from Table VI that 18% of the trees are common to all the five stands and 33% are common to the first four types thus showing a high degree of homogeneity. A frequency diagram after Raunkiaer (1934) is drawn in Fig. 2 for all the types put together. This also shows the normal diagram indicating homogeneity of the stands (cf. Oosting, 1948).

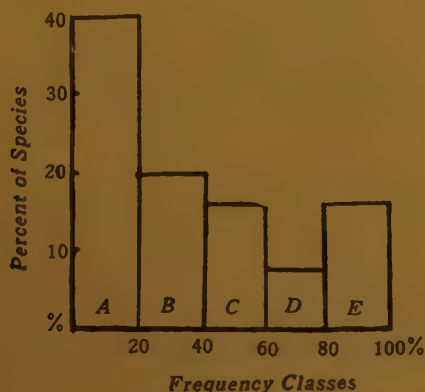


FIG. 2. Frequency diagram of the forest-complex including all the types

There seems to be indeed a basic community of forest growth throughout the area with local biotic and edaphic variants. The dominant species of the basic forest would appear to be *Diospyros melanoxylon*, *Terminalia tomentosa*, *Anogeissus latifolia* and *Butea frondosa*. Of these the first and the last increase in proportion to biotic disturb-

TABLE VI
Sociological values for the five forest types

Species	Frequency					Abundance					Dominance					Sociability				
	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
A—Present in 5/5 stands																				
<i>Diospyros melanoxylon</i> Roxb.	..	5	5	5	5	5	4	4	4	4	5	2	3	3	3	4	3	3	3	3
<i>Butea frondosa</i> Roxb.	..	5	5	4	4	5	4	4	2	3	5	1	2	2	2	3	2	3	2	2
<i>Terminalia tomentosa</i> W. and A.	..	5	4	5	3	1	3	2	4	2	1	2	2	3	2	1	2	2	2	2
<i>Flacourtia ramontchi</i> L' Hevit.	..	5	2	2	3	5	4	2	1	1	2	2	2	1	1	2	2	1	1	1
<i>Lasianthus parviflora</i> Roxb.	..	3	4	2	3	4	1	4	2	1	2	1	3	2	1	2	2	2	2	1
<i>Cassia fistula</i> Linn.	..	3	2	3	4	3	2	1	2	1	2	1	1	2	1	2	1	1	1	1
B—Present in 4/5 stands																				
<i>Anogeissus latifolia</i> Wall.	..	5	5	5	5	..	4	4	4	4	..	3	3	3	3	..	3	3	3	3
<i>Saccolobium tomentosum</i> H.F. and T.	..	5	4	2	3	..	2	3	3	1	..	2	2	2	2	..	2	2	3	2
<i>Odina walteri</i> Roxb.	..	4	3	3	4	..	3	2	3	2	..	2	2	2	2	..	1	1	1	1
<i>Stephogyne parvifolia</i> Korth.	..	4	..	2	4	2	3	..	1	3	1	2	..	1	2	1	3	..	1	3
<i>Acacia catechu</i> Willd.	..	3	2	2	2	..	2	1	1	1	..	2	1	1	1	..	2	2	2	2
<i>A. leucophlea</i> Willd.	..	3	1	3	..	4	2	1	1	..	2	2	1	1	..	2	1	1	1	..
<i>Eleodendron glaucum</i> Pers.	..	1	3	2	2	..	1	1	1	1	..	1	1	1	1	..	1	2	1	1
C—Present in 3/5 stands																				
<i>Dalbergia paniculata</i> Roxb.	..	3	..	2	2	..	2	..	1	1	..	1	..	1	1	..	1	..	1	1
<i>Gardenia latifolia</i> Ait.	..	3	..	2	2	..	2	..	2	2	..	2	..	2	2	..	1	..	2	2
<i>Holoptelea integrifolia</i> Planch.	..	2	1	..	..	3	2	1	..	..	2	1	1	..	..	2	2	1	..	..
<i>Bauhinia purpurea</i> Linn.	..	2	..	2	3	..	2	..	3	3	..	1	..	2	2	..	1	..	1	2
<i>Wrightia tinctoria</i> R. Br.	..	2	..	2	3	..	2	..	2	1	..	1	..	2	2	..	2	..	3	2
<i>Aegle marmelos</i> Correa.	..	2	..	1	5	..	1	..	1	4	..	1	..	1	3	..	3	..	3	3
<i>Bridelia retusa</i> Spreng.	..	2	1	..	..	2	1	1	..	..	1	1	1	..	..	1	1	1	..	..
<i>Buchanania lanzan</i> Spreng.	..	1	2	2	..	..	1	1	1	..	..	1	1	1	..	..	1	1	1	..
<i>Ixora parviflora</i> Vahl.	..	1	1	1	..	..	1	1	1	..	..	1	1	1	..	..	1	2	2	..
D—Present in 2/5 stands																				
<i>Tectona grandis</i> Linn.	..	5	..	..	2	..	4	..	..	2	..	3	..	..	2	..	3	..	..	2
<i>Phyllanthus emblica</i> Linn.	..	3	..	2	..	..	2	..	1	..	..	1	..	1	..	..	8	..	1	..
<i>Bombax malabaricum</i> D.C.	..	1	..	..	..	1	1	..	..	..	1	1	..	..	..	1	1	..	..	..
<i>Schleichera oleosa</i> (Lour.) Mer.	2	2	..	..	..	2	2	..	..	..	2	2	..	..	..	3	3	..
E—Present in 1/5 stands																				
<i>Zizyphus xylopyra</i> Willd.	..	5	..	..	..	..	8	..	..	..	..	2	..	..	..	..	2	..	..	..
<i>Kydia calycina</i> Roxb.	..	5	..	..	..	..	2	..	..	..	..	2	..	..	..	..	4	..	..	..
<i>Nyctanthes arborescens</i> Linn.	..	3	..	..	..	..	2	..	..	..	..	2	..	..	..	..	4	..	..	..
<i>Careya arborea</i> Roxb.	..	3	..	..	..	..	2	..	..	..	..	1	..	..	..	..	1	..	..	..
<i>Albizia odoratissima</i> Benth.	..	1	..	..	..	..	1	..	..	..	..	1	..	..	..	..	1	..	..	..
<i>Ougeinia dalbergioides</i> Benth.	..	1	..	..	..	..	1	..	..	..	..	1	..	..	..	..	2	..	..	..
<i>Bassia latifolia</i> Roxb.	2	..	..	..	..	1	..	..	..	..	1	..	..	..	..	1	..
<i>Zizyphus jujuba</i> Lamk.	1	..	..	..	..	1	..	..	..	..	1	..	..	..	..

ances, the second on maturity and stability of soil and the third on eroded substrata.

It is interesting to note that quite a number of species occur almost in all the types and therefore the number of characteristic species for them is small. However, type 1, i.e., the teak forest, is different from the rest in having a high degree of fidelity for as many as six exclusive species, three selectives and a number of preferants (cf. Table VI). Types 1-4 show a high incidence of *Anogeissus latifolia*, which is an indicator of monsoon erosion. *Lagerstræmia parviflora* is a characteristic of poor sandy soil and is outnumbered by *Terminalia tomentosa* on improvement and stabilisation of the soil as in type 3. *Aegle marmelos* appears to be an indicator of a well drained lime and clay rich soil associated with the outcropping of the intertrappeans as in type 4. *Diospyros melanoxylon* and *Butea frondosa* are present throughout the forests and can withstand biotic disturbances to a high degree. Indeed their high incidence in all the types is suggestive of the universal effects of anthropogenic factors.

V. SUCCESSION IN THE FOREST

Taking into consideration the maturity of the soil, the climatic climax of the region appears to be a mixed deciduous forest somewhat similar to type 3 described in this paper. *Diospyros melanoxylon*, *Butea frondosa* and *Terminalia tomentosa* will be the dominant species of such a forest. *Tectona grandis* appears to be a codominant in most of the neighbouring forests on light lateritic soil. The seral stages leading to the climax community are largely edaphic and physiographic in character. Biotic factors working at different stages set up secondary successions but since erosion of the soil may start on denudation of the plant cover, the intensity of such factors is an important consideration. The seral communities for both the 'prisere' and the 'subser' indeed in many instances become indistinguishable. A schematic representation of the successions for the present study is given below:—

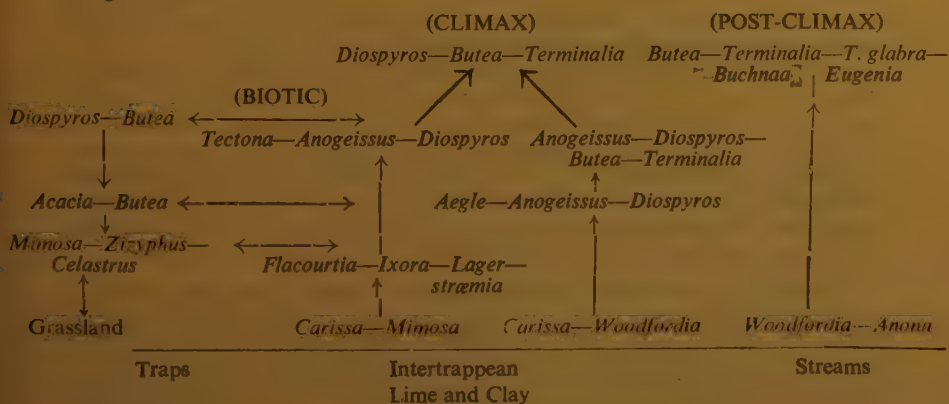


FIG. 3. Succession Diagram of Patharia Forest-Complex

The early stages of the succession are characterised by the presence of thorny shrubs like *Carissa spinarum*, *Flacourtia ramontchi*, *Zizyphus ænoplia*, etc. These species not only stabilise the substratum but provide effective shelter to tree seedlings against grazing. Misra (1944) has shown in his study of the ravines of Rajghat (Banaras) that species capable of regeneration from exposed roots can thrive best on eroding land. In the present study most of the shrubs like *Carissa spinarum*, *Woodfordia floribunda*, *Mimosa rubicaulis*, *Ixora parviflora*, *Anona squamosa*, etc., all early colonisers on the hill sides, possess this faculty. *Helictres isora* in the teak forest is a late arrival which can thrive better under shade.

At the foot of the hills where deposition of soil is a characteristic feature, *Zizyphus rotundifolia* plays the rôle of pioneer species. Shoots arise from the basal parts of the stem of this plant on being covered by soil. It is just an antithesis of *Carissa spinarum*, in which erosion exposes root buds for growth. In the former case soil deposition covers shoot buds which subsequently root.

VI. DISCUSSION

Pure stands in forests may be obtained either by uniformity of soil, climate and biotic factors, wherein dominant species may reduce or eliminate their associates in due course, or by the growth of such trees which possess too wide ecological amplitude to cover all the major variations present in the environment.

On account of erosion, supplemented with and accelerated by biotic disturbances, the soil on the ridges remains immature with frequent outcropping of the substratum. Further, the spatial distribution of basalt, clay and lime gets changed in course of time on the slopes. Hence uniformity in the environment with respect to the edaphic factors is lacking and this might explain the absence of pure stands in the area. However, on the terraces and the plateau intermixed soil of sedentary and transported origin may accumulate with the growth of the vegetation. As the thickness of the soil would increase one may expect to get pure stands of *Terminalia tomentosa* upon it. The intensity of the biotic factors, however is most severe at such places. This leads to the growth of *Butea frondosa*, *Diospyros melanoxylon* and *Acacia leucophlæa* here. *Anogeissus latifolia*, on the other hand, is unable to compete successfully with the other species on stabilisation of the soil. Thus the dominant species of the basic community do not seem to be sufficiently aggressive in all the available situations. Different species keep on colonising with the environmental flux, thus resulting in the development of a mixed forest.

It might be said that most of the forest types represent only seral communities and hence pure stands do not develop. It has been shown, however, that the entire forest-complex possesses a high degree of homogeneity so as to give a fair chance to the dominant species developing into pure stands, even though the types represent mostly seral units. Yet they fail to do so on account of lack of ac-

commodation in them for the heterogeneity in the environmental complex. The edaphic and the biotic factors very strongly influence the composition of the seral communities. There is thus every reason for the growth of mixed forests and the hypothesis enunciated in the introduction of this paper seems to be well established.

VII. SUMMARY

1. The study is based upon forests growing on a ridge near Sagar known as Patharia hill.

2. Climate, geology and soil of the area have been described and emphasis has been laid upon the physiographic and biotic factors obtaining on the hill.

(a) Annual rainfall is about 50 inches mostly precipitating in July, August and September. November, December, January and February months are cool with a temperature range of 39° to 80° F. The warmer period may show a temperature range of 75° F. to 115° F.

(b) The hills consist of trap with frequent intertrappean deposits of clay, lime and ash. The soil is grey coloured sandy loam.

(c) On account of intense erosion, the soil remains at most of the places immature with frequent outcroppings.

(d) Anthropogenic factors keep on disturbing the equilibrium of forest—substratum growth.

3. Seven types of forest communities are recognised in the study. Sociological data for the tree, shrub and herb layers together with the habitat factors are given for each type.

4. A basic type of forest has been postulated from which the variants are supposed to have been derived according to the intensity of the most operative factor.

5. A scheme showing the succession in the forest types has been drawn up.

6. The mixed character of the forest-complex has been ascribed to edaphic conditions and seral growth obtaining in the area.

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LITERATURE CITED

1. BRAUN BLANQUET, J. 1932. *Plant Sociology*. New York.
2. BROWN, D. M. 1941. The Vegetation of Roan Mountain. A Phytosociological and successional study. *Eco. Mon.* 2: 1.
3. CHAMPION, H. G. 1936. Preliminary Survey of the Forest Types of India and Burma. *Ind. For. Rec. (New Ser.)* 1.
4. GATES, F. C. 1949. *Field Manual of Plant Ecology*. New York.

5. LUCY BRAUN, E. 1940. An Ecological Transect of Black Mountain, Kentnely
Eco. Mon. 10: 2.
6. ————. 1942. Forest of Cumberland Mountains. Eco. Mon. 20: 4.
7. MISRA, R. 1944. The Vegetation of Rajghat Ravines. Jour. Ind. Bot. Soc.
24: 3.
8. ————. 1946. A Study in the Ecology of Low-lying Lands. Ind.
Eco. 1: 1.
9. OOSTING, H. J. 1948. The Study of Plant Communities. California.
10. POTZER, J. E. 1946. Phytosociology of the Primeval Forest in Central
Northern Wisconsin and Upper Michigan and a Brief Post-Glacial History
of the Lake Forest Formation. Eco. Mon. 16: 3.
11. RICHARDS, P. W. 1939. Ecological Studies in the Rain Forest of Southern
Nigeria I. Journ. Eco. 17: 1.
12. RAUNKIAER, C. 1934. The Life-Forms of Plants and Statistical Plant
Geography. O.U.P.

FLORAL ANATOMY OF SOME MALVALES AND ITS BEARING ON THE AFFINITIES OF FAMILIES INCLUDED IN THE ORDER

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IN a previous article on the floral anatomy of some Sterculiaceæ (Rao, 1949 b), it was pointed out that contrary to the description given in several books, the andrœcium in the family consists of an outer antipetalous fertile whorl which undergoes chorosis and an inner staminodal whorl which may sometimes be suppressed. In the present paper, the results of the study of the floral anatomy of some more members of Malvales are presented. The floral anatomy of the following plants was studied:

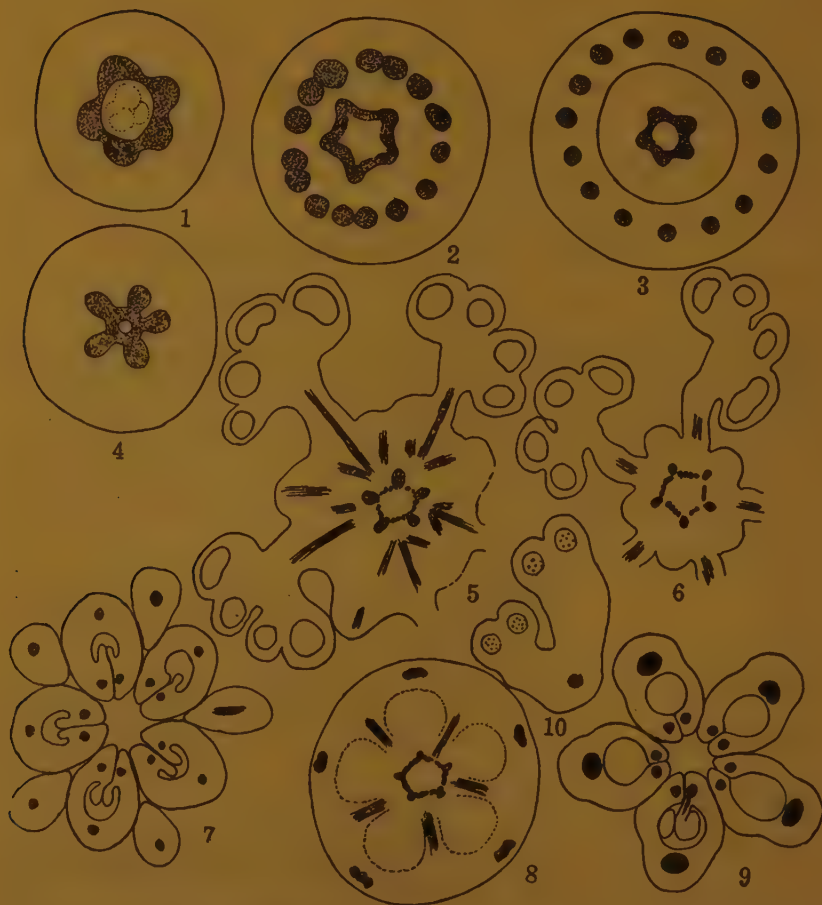
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|--------------|----|---|
| STERCULIACEÆ | .. | <i>Sterculia fætida</i> L.; <i>Pentapetes phænicea</i> L.; <i>Klienhowia hospita</i> L.; <i>Abroma augusta</i> L.; <i>Buettneria herbacea</i> Roxb.; <i>Melochia corchorifolia</i> L.; and <i>Waltheria indica</i> L. |
| TILIACEÆ | .. | <i>Corchorus acutangulus</i> Lam.; <i>Triumfetta rhomboidea</i> Jacq.; and <i>Triumfetta rotundifolia</i> Lam. |
| ELÆOCARPACEÆ | .. | <i>Muntingia calabura</i> L. and <i>Elæocarpus robustus</i> Roxb. |
| BOMBACACEÆ | .. | <i>Bombax malabaricum</i> D.C. |
| MALVACEÆ | .. | <i>Malvaviscus arboreus</i> Cav.; <i>Hibiscus solandra</i> L. Herit.; <i>H. micranthus</i> L.; and <i>Abutilon indicum</i> G. Don. |

The large flowers of *Bombax* were studied by taking freehand sections. In the remaining plants, serial microtome sections stained in safranin and fast green were studied.

Sterculia fætida L.

Sterculia fætida L. differs from other genera of the family in having apetalous and unisexual flowers. The abortive non-functional organs are found in both kinds of flowers. The flowers are pentamerous and provided with a gynandrophore. The andrœcium is constructed in $S_{(3)} + 5$ plan both whorls of stamens being fertile in the male flowers. The gynœcium consists of five free carpels which are united by the style. Each carpel has several ovules on marginal placenta and presents a typical leaf-like appearance.

From the stele of the receptacle, traces for the five sepals are first given off (Fig. 1) each of which divides into 3 bundles (Figs. 2 and 3).



FIGS. 1-7. Floral anatomy of male flower and FIGS. 8-10, of female flower of *Sterculia foetida*.—Fig. 1. Stele of pedicel showing the formation of sepal traces. Fig. 2. Division of sepal traces and formation of the outer whorl of staminal traces. Fig. 3. Gynandrophore surrounded by calyx cup. Fig. 4. Gynandrophore with staminal traces. Fig. 5. Branching of the outer staminal traces and organisation of traces for the inner whorl of stamens. Fig. 6. Emergence of the inner staminal traces and organisation of dorsal carpellary traces. Fig. 7. Pistilode and filaments of the inner whorl of stamens. Fig. 8. T.s. top of column of female flower showing lobing of the outer staminodal traces and emergence of inner staminodal traces and formation of dorsal carpellary traces. Fig. 9. Apocarpous pistil. Fig. 10. A staminode from female flower. FIGS. 1-3, $\times 9$; FIG. 4, $\times 30$; FIGS. 5 and 6, $\times 15$; FIGS. 7-9, $\times 30$; FIG. 10, $\times 75$.

The traces for the outer whorl of stamens which are alternisepalous, are organised in close succession even at the base of the gynandrophore (FIGS. 2-4). These, however, do not separate at this level but only at the top of the column. Each trace divides into three staminal

bundles, which pass independently into the filaments of the outer whorl of stamens (Fig. 5). The traces for the inner whorl of stamens are given off on the sepal radii and pass on without branching into the inner group of five stamens (Fig. 6). In the male flower, as in the female flower, the residual stele breaks up into the five dorsal carpellary traces and the 10 ventral bundles, which enter the five carpels (Figs. 7 and 9). The anthers in the female flower show abortive pollen grains, just as the pistilode in the male flowers shows abortive ovules (Figs. 7 and 10).

Pentapetes phœnicea L.

The flower of *Pentapetes phœnicea* L. shows an epicalyx of two-three bracteoles, a dichlamydeous polyphyllous perianth and andræcium of five groups of stamens (each of three), alternating with five petaloid staminodes. The gynæcium is five-carpellary, syncarpous, with several ovules on axile placentæ.

The vascular cylinder of the pedicel undergoes secondary thickening due to the activity of a cambium ring (Fig. 11). From this are given off the traces to bracteoles (Fig. 11) and then to the sepals (Fig. 12). The conjoint petal-stamen traces which are given off next alternate with the sepal radii, get tangentially stretched as they bend outwards. After giving off the sepal commissurals (Fig. 14), they divide in a radial manner to form the smaller petal traces and the larger staminal traces (Fig. 15) as in *Pterospermum acerifolium* (Rao, 1949 b). Each of the staminal traces divides into three bundles (Fig. 16). A little above the emergence of the petal-stamen traces, five traces are given off on the sepal radii for the inner whorl of staminodes (Fig. 14). These bend outwards without branching and emerge along with the staminal bundles into the staminal tube (Fig. 16), which later splits into the filaments of the stamens and staminodes (Fig. 18).

At the base of the ovary, the five dorsal carpellary traces are given off on the petal radii (Fig. 14), so that the loculi are originally antipetalous in position though the asymmetrical growth of the petals disturbs this alignment higher up. Each dorsal trace splits up radially into two bundles which run parallel to each other along the midribs of carpels (Fig. 17). The residual stele of the receptacle again closes up to form a ring (Fig. 17) and breaks up a little higher into the 10 ventral bundles (Fig. 18). The two ventral bundles at the base of each septum fuse and form the common bundle, from which the ovular traces are given off (Fig. 19). Towards the top of the ovary, the three bundles of each carpel again fuse and form a single bundle, which runs in one of the five lobes of the style. The five carpels of the ovary do not fuse at the centre, but leave a five-angled axial space (Fig. 19) which extends upto the base of the style.

Pentapetes resembles the other genera of Dombeyæ, namely, *Dombeya* and *Pterospermum* (Wight, 1840; Rao, 1950), in the presence of pentacyclic flowers, in the origin and behaviour of petal-stamen traces and in the $5_{(3)} + 5$ plan of the andræcium. That these three genera form a natural group is further evident by the presence of epi-



FIGS. 11-21. Floral anatomy of *Pentapetes phanicea*.—Fig. 11. Stele of pedicel and bracteole traces. Fig. 12. Traces for sepals being given off. Fig. 13.

Sepal bundles and conjoint petal-stamen traces seen to the outside of main stele. Fig. 14. Branching of conjoint traces to form sepal commissurals; staminodal and dorsal carpellary traces seen. Fig. 15. Branching of petal-stamen traces. Fig. 16. Separation of petals and staminal tube; dorsal carpellary bundles and ventral bundles seen. Fig. 17. Ventral bundles unite to form a continuous vascular cylinder. Fig. 18. Staminal tube splits into filaments of stamens and staminodes. Fig. 19. Ovary showing formation of ovular traces from common bundles. Fig. 20. Style, some stamens and staminodes. Fig. 21. Base of style showing stylar canal and five vascular bundles. Figs. 11-15, $\times 9$; Figs. 16-18, $\times 10$; Fig. 19, $\times 15$; Fig. 21, $\times 45$.

calyx, a conspicuous corolla with asymmetrical petals and contorted aestivation, and spinescent three-porate pollen grains (Rao, 1950).

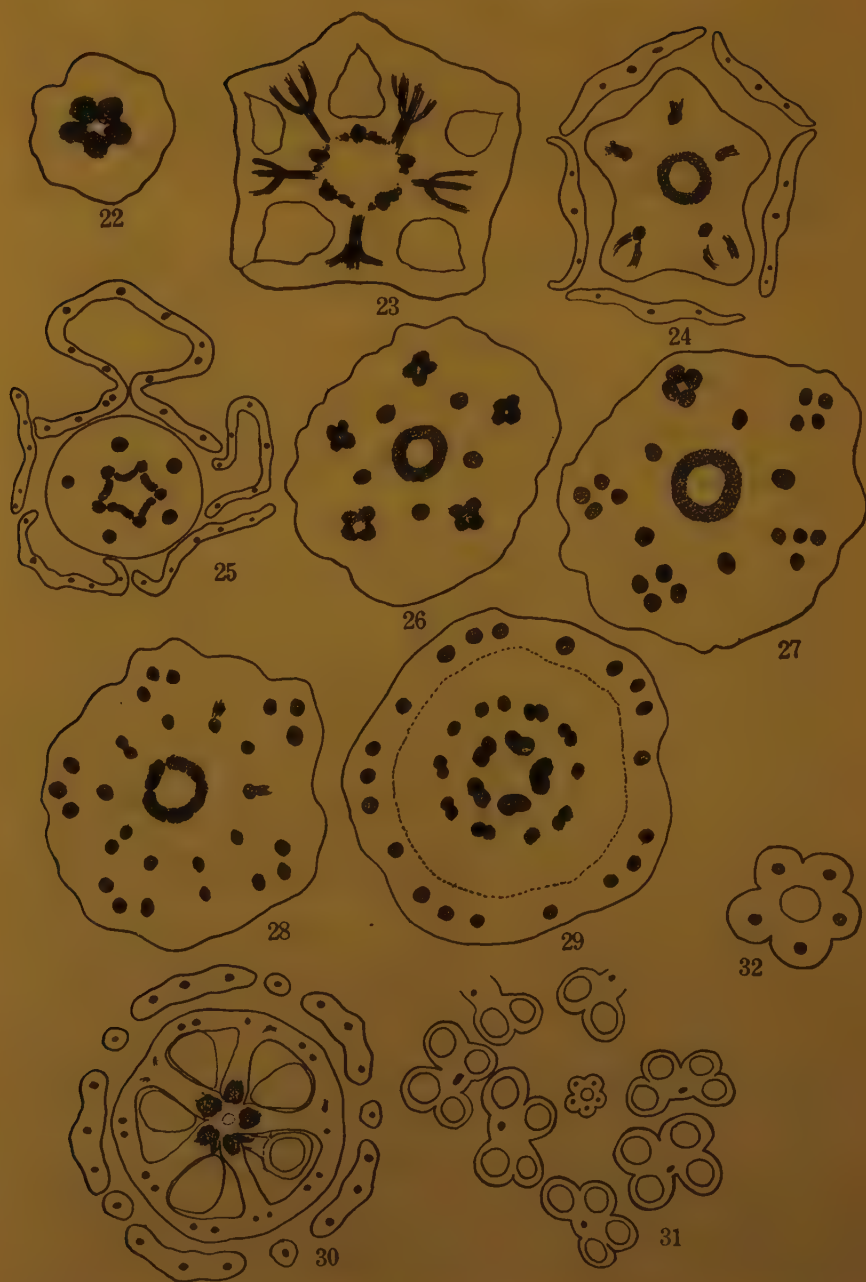
Klienhowia hospita L.

The flower of *Klienhowia hospita* L. shows a zygomorphic corolla with a dissimilar posterior petal. The essential organs are raised upon a gynandrophore. The andræcium, as in *Dombeya*, is constructed in $5_{(3)} + 5$ plan. There are two or three ovules in each of the five loculi of the ovary.

The traces which are given off alternate to the sepal traces (Fig. 22) represent the conjoint petal-stamen traces to which the dorsal carpellary traces are also adnate (Fig. 23). Each of these, first splits tangentially and forms the petal traces to the outside (Fig. 24). The traces formed to the inside traverse the whole length of the gynandrophore forming a ring around the main stele (Fig. 25). Towards the top of the column each trace becomes four-lobed (Fig. 26) and divides in such a manner that three staminal bundles are formed to the outside and the dorsal carpellary trace to the inside (Fig. 27). Meanwhile the five staminodal traces are given off from the main stele (Fig. 25) alternating with the traces of the previous whorl. These bend outwards and split tangentially (Fig. 28). The five bundles formed to the outside represent the staminodal traces. These occupy the gaps between the groups of staminal bundles and emerge along with them into the staminal tube (Fig. 29).

The five dorsal carpellary traces and five bundles derived by splitting of the staminodal traces form a ring around the residual stele at the base of the ovary (Fig. 29). They then split into two each. Five pairs of bundles traverse the midribs of carpels, while the remaining five pairs traverse the ovary wall to the outside of the septa as median laterals. The centrally placed vascular tissue splits up and forms the ten ventral bundles from which the ovular supply is derived. The style shows a well marked stylar canal (Fig. 32).

Klienhowia and *Helicteres* belong to the tribe Helicteræ. They resemble each other in the possession of zygomorphic flowers, a gynandrophore and the presence of triangular oblatly flattened three-porate pollen grains. Anatomically *Klienhowia* resembles *Dombeya* in the vascular plan of the andræcium. There is particular resemblance to *Pterospermum* in the origin of some of the ovarian bundles from those of the stamens. *Helicteres* resembles *Klienhowia* in the



FIGS. 22-32. Floral anatomy of *Klienhowia hospita*.—Fig. 22. Stele of pedicel. Fig. 23. Sepal traces given off. Fig. 24. Conjoint petal-stamen traces divide into

the component traces. Fig. 25. Gynandrophore with corolla surrounding it; in the stele of the gynandrophore are seen the staminal and staminodal traces. Fig. 26. Division of the staminal traces into four bundles. Fig. 27. Staminodal traces form a ring with the dorsal carpellary traces. Fig. 28. Branching of staminodal bundles. Fig. 29. Staminodal and staminal bundles emerge into staminal tube; the inner bundles form a ring outer to the main stele. Fig. 30. Staminal tube splits up into staminodal and staminal filaments; inner bundles enter the ovary wall; ventral carpellary bundles seen. Fig. 31. Style and some stamens. Fig. 32. Style showing five vascular bundles and the styler canal. Fig. 22, $\times 30$; Figs. 23-25, $\times 20$; Figs. 26-29, $\times 45$; Figs. 30 and 31, $\times 40$; Fig. 32, $\times 90$.

construction of the outer whorl of andræcium in $5_{(3)}$ plan though the median member of each group becomes staminodal. The flowers of *Helicteres* are tetracyclic owing to the suppression of the inner whorl of andræcium.

Abroma augusta L.

The flowers of *Abroma augusta* L. resemble those of *Dombeyea* and *Klienhowia* in being pentacyclic and showing $5_{(3)} + 5$ andræcium. The petals which are concave at base, show strap-shaped appendages. The ovary consists of five carpels with numerous ovules on axile placentæ in each of the five loculi.

The origin and behaviour of the sepal, conjoint petal-stamen and staminodal traces are closely similar to those in *Pentapetes phanicea* (Figs. 33-36). The median stamen of the triplets of the outer whorl gets separated from the staminal tube a little earlier than the laterals (Figs. 37 and 38). The staminodes are petaloid (Fig. 39). The vasculature of the ovary and style resembles that of *Pentapetes*.

Buettneria herbacea Roxb.

Like those of *Abroma*, the flowers of *Buettneria* are pentacyclic and provided with appendaged petals. The andræcium is typically obdiplostemonous consisting of five antipetalous stamens and five staminodes, all of which are connate below. The gynoecium is similar to that of *Klienhowia*.

The conjoint petal-stamen traces which are given off alternate to the sepal traces, divide tangentially and demarcate the petal traces to the outside and staminal traces to the inside (Figs. 41 and 42). The latter, like the staminodal traces which are given off next, pass outwards without branching into the staminal tube (Fig. 43). This splits into the filaments of stamens and staminodes higher up (Figs. 44 and 45).

Abroma and *Buettneria* belong to the tribe Buettneriæ. The andræcium of *Abroma* resembles that of *Dombeyea* and *Klienhowia* in showing $5_{(3)}$ stamens and five staminodes. In *Buettneria*, on the other hand, due to the suppression of branching of the outer staminal traces, it becomes typically obdiplostemonous. Other members of the tribe like *Guazuma tomentosa* resemble *Abroma*, while *Theobroma cacao* resembles *Buettneria* in the structure of the andræcium.



FIGS. 33-39. Floral anatomy of *Abroma augusta*.—Fig. 33. Stele of pedicel showing branching of sepal traces and organisation of conjoint petal-stamen

traces. Fig. 34. Division of conjoint traces; traces for inner whorl of staminodes and dorsal carpellary traces seen. Fig. 35. Petals separating from staminal tube, the latter showing the division of outer staminal traces and inner staminodal traces. Fig. 36. Ovary surrounded by staminal tube; outer staminal traces divided into three bundles each. Fig. 37. Staminal tube showing emergence of median stamens of the triplets of outer whorl, and ovary. Fig. 38. Splitting of staminal tube into stamens and staminodes. Fig. 39. Style surrounded by staminodes. Figs. 40-45. Floral anatomy of *Buettneria herbacea*. Fig. 40. Stele of pedicel showing emergence and branching of sepal traces. Fig. 41. Organisation of conjoint petal-stamen traces. Fig. 42. Division of conjoint traces and organisation of inner whorl of staminal traces. Fig. 43. T.s. flower bud showing sepals, clawed petals, staminal tube with bundles of both whorls of stamens and ovary. Fig. 44. Emergence of outer whorl of stamens. Fig. 45. Petals staminodes and style. Figs. 33-45, $\times 15$.

Melochia corchorifolia L. and *Waltheria indica* L.

Melochia and *Waltheria* belong to the tribe *Hermannieæ* of *Sterculiaceæ*. In both species, the origin and emergence of the sepal and conjoint petal stamen traces are closely similar to those in the previously studied genera. However, due to the suppression of branching of the outer staminal traces and the complete suppression of the inner whorl of staminodal traces, the andræcium consists of only five anti-petalous stamens and the flowers consequently become tetracyclic. The ovary in *Melochia* shows five antipetalous carpels with two ovules in each, while that of *Waltheria* is unilocular with two marginally placed ovules.

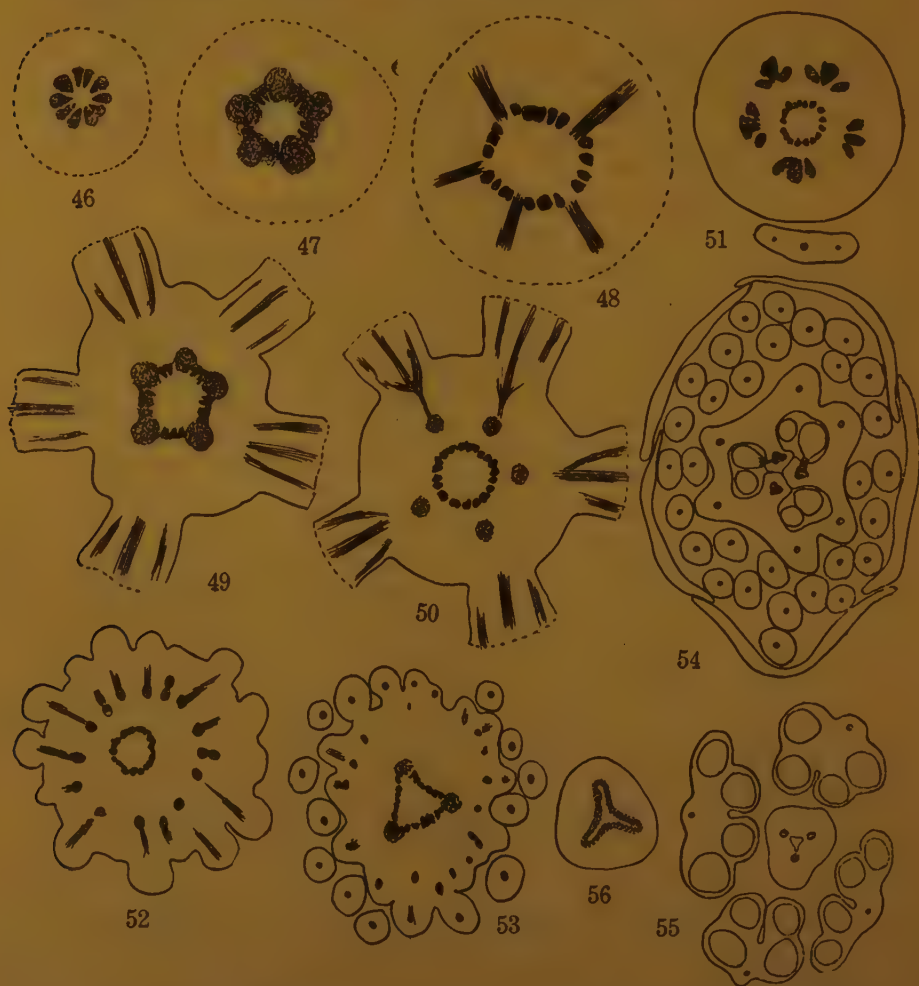
Gerard (1938, 1940) who studied the floral anatomy of some members of *Sterculiaceæ*, discarded the views of both Eichler (that the stamens are epipetalous) and Baillon (that they are episepalous) and put forward the view that they are pseudo-obdiplostemonous. He divided the family into two sub-families, the first comprising *Eriolaneæ*, *Dombeyeæ*, *Helicteræ* and *Hermannieæ* and the second, the *Buettnerieæ*, *Sterculieæ* and *Lasiopetaleæ*. He described that in the first group, the traces for the outer fertile whorl of stamens arise exactly superposed to the sepaline traces, that there are no true petals because there are no separate petal traces departing from the main stele and what appear as petals are not petals in the strict morphological sense but only 'auxiliary petaloid staminodes' which are fed by branches of the staminal traces. On the other hand, he believed that in the second sub-family there were true petals since they had independent traces.

The writer's observations, however, show that the petals in the whole family are homologous. It is not a case of the branches of the staminal traces feeding the petaloid staminodes but an adnation of the petal and antepetalous staminal traces, hence a case of 'obdiplostemony'. The apparent superposed position of the conjoint petal-stamen traces and the sepal traces is due to the closeness of their origin; the conjoint traces sometimes arise from the stele even before the gaps of sepaline traces have closed completely.

Corchorus acutangulus Lam.

The flowers of *Corchorus acutangulus* Lam. show pentamerous polyphyllous perianth and numerous stamens with ditheous introrse

anthers in five antipetalous groups. The gynoecium is tricarpellary, syncarpous, trilocular with numerous ovules on axile placentæ. The style is short and shows a triangular styler canal which is lined by radially elongated richly protoplasmic cells (Fig. 56).



FIGS. 46-56. Floral anatomy of *Corchorus acutangulus*.—Fig. 46. Stele of pedicel. Fig. 47. Formation of sepal traces. Figs. 48 and 49. Emergence of sepal traces and origin of petal-stamen traces. Fig. 50. Division of petal-stamen traces into component traces. Fig. 51. Primary division of the staminal traces into three bundles. Fig. 52. Secondary splitting of staminal bundles. Fig. 53. Emergence of staminal bundles and the origin of dorsal carpellary traces. Fig. 54. Ovary with dorsal and ventral carpellary bundles; the filaments of the stamens are seen to the outside. Fig. 55. Style with vascular bundles; some stamens are seen to the outside. Fig. 56. Top of the style with the stigmatic furrow. Figs. 46-55, $\times 45$; Fig. 56, $\times 75$.

Alternating with the sepal traces are given off the conjoint petal-stamen traces (Figs. 47-49). Each of these splits up and forms the petal trace to the outside and staminal trace to the inside (Fig. 50). The petal trace splits up and forms three petal bundles which enter the bases of petals (Fig. 50). The staminal traces become tangentially stretched and as in *Sterculiaceæ*, undergo a primary splitting into three bundles each (Fig. 51). But instead of entering directly into the filaments of stamens, they undergo a secondary splitting and give rise to 25-35 staminal bundles (Figs. 52-54). The inner staminal whorl is completely suppressed, and the flowers are tetracyclic.

At the base of the ovary, the stele becomes triangular in outline (Fig. 53). From each angle, a dorsal carpellary trace is given off and the residual stele breaks up into the six ventral bundles. Each dorsal trace splits into two bundles and the six bundles thus formed, traverse along the inside of the six ridges of the ovary wall, giving off smaller strands which feed the ovary wall (Fig. 54). The common bundles formed by the fusion of the two ventral bundles at the base of each septum give off the ovular traces (Fig. 54).

Corchorus resembles genera of *Sterculiaceæ* in the origin and emergence of traces for sepals, petals and stamens. The only variation is that in this, the staminal traces undergo a secondary chorosis which is associated with the great increase in the number of stamens.

***Triumfetta rhomboidea* Jacq.**

The flowers of *Triumfetta rhomboidea* are pentamerous with dichlamydeous and polyphyllous perianth. The surface of the thalamus inner to the bases of petals, is glandular. There are 10 stamens in five antipetalous pairs. The ovary is bicarpellary, syncarpous with two ovules in each carpel, which are axile and pendulous. The ovary shows a number of glandular protuberances and terminates in a solid filiform style.

The pedicel shows a closed ring of vascular bundles surrounding a mucilage cavity (Fig. 57). The sepal traces and the conjoint petal stamen traces arise and emerge as in *Corchorus* (Figs. 58 and 59). By splitting tangentially, the conjoint traces form the petal traces to the outside and staminal traces to the inside (Fig. 59). The former bend outwards towards the circumference of the receptacle while the staminal traces continue their course vertically upwards forming a ring to the outside of the main stele. Each petal trace during its course, divides tangentially and forms a small strand to the inside and the petal trace proper to the outside (Fig. 60). The inner bundle proceeds upwards and outwards and divides radially into two strands (Fig. 61). These enter and fade out in a zone of large thin-walled richly protoplasmic cells which bear on the outside, numerous multicellular glandular hairs (Figs. 62 and 63). The five staminal traces divide radially into two bundles each. The ten bundles thus formed enter the filaments of the five pairs of stamens (Fig. 65). In respect of the emergence of the staminal bundles after the primary splitting of the staminal traces *Triumfetta rhomboidea* resembles members of *Sterculiaceæ*.



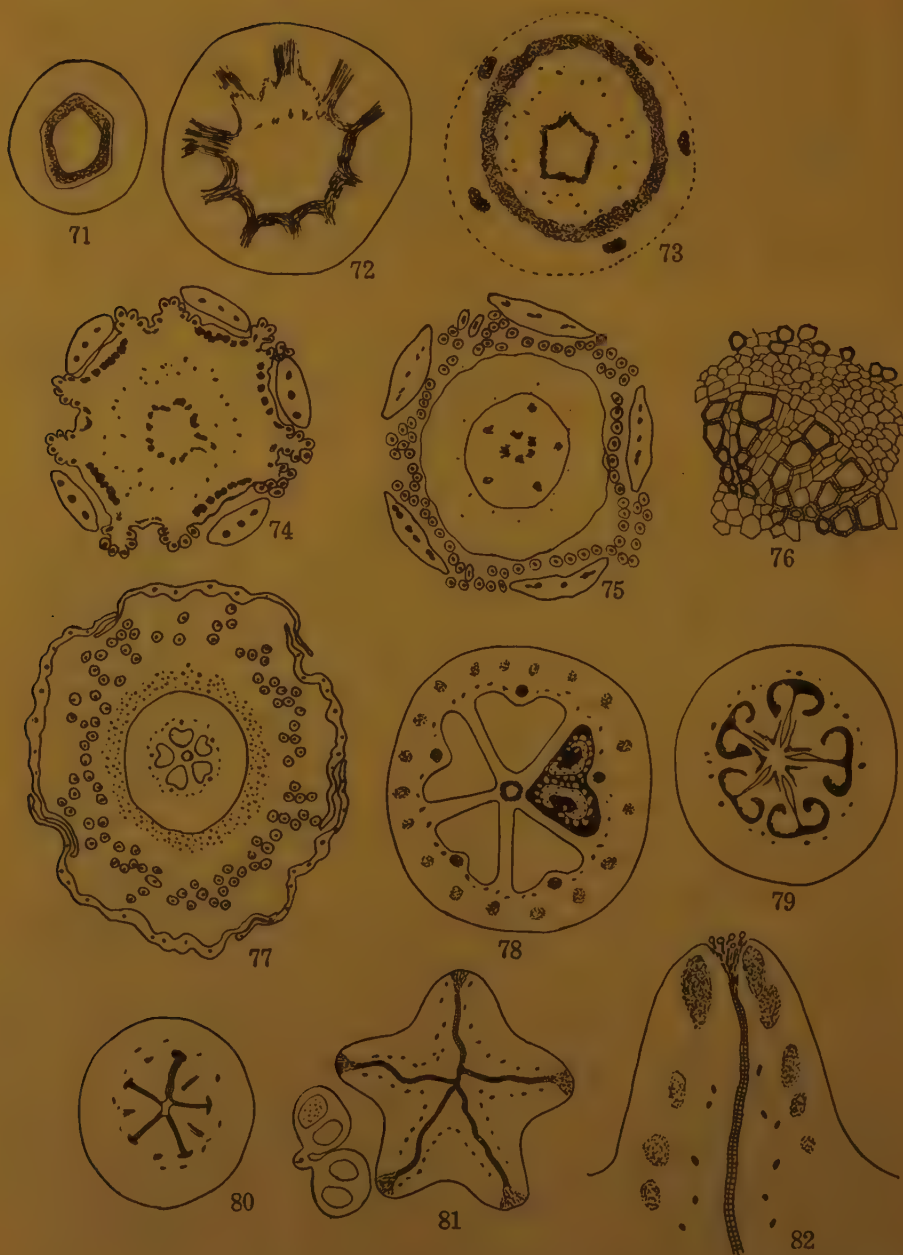
Figs. 57-70

FIGS. 57-70. Floral anatomy of *Triumfetta rhomboidea*.—Fig. 57. Stele of pedicel. Fig. 58. Origin and emergence of sepal traces. Fig. 59. Origin and division of conjoint petal-stamen traces. Fig. 60. Stele with staminal traces; the petal traces divide to form petal bundles and accessory strand for the nectary. Fig. 61. Stele of the receptacle surrounded by staminal traces; the bundles which feed the glandular zones are seen near the circumference while petals are seen to the outside. Fig. 62. Zones of glandular hairs seen to the inside of petal bases; staminal traces are seen. Fig. 63. A zone of glandular hairs magnified. Fig. 64. Staminal traces bifurcate. Fig. 65. Dorsal carpellary traces formed. Fig. 66. Division of carpellary traces; filaments of stamens are seen to the outside. Fig. 67. Ventral bundles and bundles of the ovary wall. Fig. 68. Section of a flower bud showing perianth, anthers and filaments of longer stamens and style. Fig. 69. Section of glandular protuberance of the ovary wall. Fig. 70. T.s. of style. Figs. 57-62 and 64-67, $\times 50$; Fig. 63, $\times 160$; Fig. 68, $\times 30$; Figs. 69 and 70, $\times 120$.

In the flowers of *Triumfetta rotundifolia* Lam., 20 stamens are seen. The staminal bundles in this species are derived from a secondary splitting of the primary staminal traces. In this feature, *Triumfetta rotundifolia* resembles *Corchorus* and also Bombacaceae and Malvaceae. There is no trace of the inner staminal whorl so that the flowers are tetracyclic.

After the departure of the petal-stamen traces, the receptacular stele contracts considerably. From its margins on the opposite sides are given off the two dorsal carpellary traces (Fig. 65). These bend outwards and split radially into two each (Fig. 66). The four bundles get equally spaced and divide into three bundles each, which traverse in one of the four lobes of the ovary wall, functioning as the dorsal carpellary trace and the median laterals (Fig. 67). After the emergence of the dorsal traces, the stele at the base of the ovary becomes H-shaped (Fig. 66). A little above, the two arms on each side get separated, as the transverse band of tissue between them fades out. These four bundles function as the ventral bundles of the two carpels. The vascular bundles of the ovary do not enter the style. Some of them enter and fade out in the glandular protuberances of the ovary wall and the rest fade out in the ovary wall itself. Each protuberance also shows a lysisgenously formed mucilage cavity (Fig. 69).

Though *Triumfetta* resembles *Corchorus* in the origin and behaviour of the conjoint petal-stamen traces, there is a little difference between them. In *Corchorus*, the staminal trace divides primarily into three bundles while in *Triumfetta* it splits up only into two bundles. Further, in *Triumfetta* the petal trace gives off a strand on its inner side which feeds a glandular structure which is not seen in *Corchorus*. From the similarity in the origin and behaviour of the petal-stamen traces in both genera, the staminal trace in *Triumfetta* also appears to be a three-bundle trace as in *Corchorus* and Sterculiaceae, but the median bundle of a triplet instead of separating along with the rest of the trace, remains adnate to the petal trace for some more distance and then separates out to feed the glandular structure. Its division into two bundles like the staminal bundle, also supports this view. Hence, each zone of glandular hairs in this genus (and probably in others with similar structure), seems to be morphologically equivalent to a staminodal nectary. The tendency for staminody of the median stamen of the triplets is also seen in *Helicteres isora* (Rao, 1949 b).



FIGS. 71-82. Floral anatomy of *Muntingia calabura*.—Fig. 71. Stele of pedicel. Fig. 72. Traces for the sepals and petals. Fig. 73. Petal traces near the circum-

ference, inner to them is the vascular cylinder for the stamens; the five-angled vascular cylinder is the supply for the ovary; in between, stray vascular bundles are seen. Fig. 74. Formation of staminal bundles and dorsal carpellary traces. Fig. 75. Gynophore with dorsal carpellary traces and ventral bundles separates from parenchymatous ring. Fig. 76. Vascular tissue in the axial region of fruit which has undergone secondary thickening. Fig. 77. Parenchymatous ring breaks up into hairs; bases of loculi appear. Fig. 78. Old ovary showing groups of stone cells outer to the ring of vascular bundles in the ovary wall. Fig. 79. Top of the ovary showing formation of placental supply strands. Fig. 80. Base of style with axial space. Fig. 81. Style with transmitting tissue; a stamen seen to the outside. Fig. 82. Part of the stigma magnified showing transmitting tissue, vascular bundles, groups of stone cells and some germinating pollen grains. Fig. 71, $\times 15$; Figs. 72-75, $\times 10$; Fig. 76, $\times 290$; Fig. 77, $\times 9$; Figs. 79-81, $\times 20$; Fig. 82, $\times 170$.

Muntingia calabura L.

The flower of *Muntingia calabura* L. shows two whorls of polyphyllous perianth and numerous stamens. The gynæcium is superior, being raised by a gynophore. It is five-carpellary, syncarpous, five-locular with numerous ovules which arise on two pendulous placentæ. The ovary terminates in a capitate, five-radiate stigma.

Mucilage sacs which form a common feature of the anatomy of the flowers of several Malvales, are absent in *Muntingia*. The petal traces are given off from the stele of the pedicel in close succession to the sepal traces, even before the gaps caused by the latter close up (Fig. 72). After the emergence of the petal traces, a continuous peripheral vascular cylinder is formed (Fig. 73). From this, several bundles are given off to the inside. Some of these bend towards the centre and form a ring which constitutes the vascular supply for the gynæcium. Some others traverse the thick parenchymatous region inner to the peripheral vascular cylinder and fade out a little above (Figs. 74 and 75). Each petal trace divides into three strands before entering a petal base (Fig. 75). The peripheral vascular plexus constitutes the vascular supply for the stamens. From the surface of this, staminal bundles are abstricted first on either side of each petal base and these emerge as five antisepalous groups of stamens (Fig. 74). As more staminal bundles are formed, the vascular zone breaks up into five antipetalous strap-shaped regions. From these, staminal bundles continue to be formed laterally and finally each zone breaks up into a linear file of antipetalous stamens (Fig. 75). Even after the separation of all the filaments, the inner parenchymatous region can be seen as a thick ring surrounding the base of the gynophore, which begins to get separated at about this level (Fig. 75). Higher up the parenchymatous zone breaks up into a number of glandular hairs (Fig. 77).

At the base of the gynophore, the vascular tissue at the centre becomes five-angled. From each angle is given off a dorsal carpellary trace (Fig. 75), which gives off strands on its way into the ovary wall. The residual stele again closes up to form a complete ring, which traverses as such to the top of the ovary (Figs. 77 and 78). As the fruit develops, this zone shows secondary thickening due to the activity of a cambium (Fig. 76). This seems to be associated with the nutrition of the very large number of seeds in each fruit. At the top of the ovary the vascular cylinder breaks up into five bundles, each of

which is situated at the base of a septum. At the level where the placentæ are attached to the septum each bundle gives off two branches (Fig. 79). These enter the placentæ, bend downwards and break up into a ring of bundles which traverse near to the surface of the placentæ and give off numerous ovular traces (Fig. 78). The residual part of the common bundle extends through the style. At the top of the ovary, the axial region splits between the septa and a five-angled space appears which closes up a little above (Figs. 80). The epidermis of the placentæ is glandular and this tissue runs continuous with the transmitting tissue of the style which appears as five radiating zones in transverse sections of the style (Fig. 81). Groups of stone cells are seen in the ovary wall on the outside of the ring of vascular bundles (Fig. 82). The vascular bundles as well as stone cells extend to the stigma, the latter forming lip-like projections on either side of the stigmatic furrow.

***Elaeocarpus robustus* Roxb.**

The flowers of *Elaeocarpus robustus* Roxb. are provided with pentamerous polyphyllous perianth, the petals being laciniate. There are 45 free stamens in two series and a tricarpellary syncarpous pistil with two axile and pendulous ovules in each loculus. Around the base of the ovary are seen five hemispherical nectaries.

Each of the five traces given off at the base of the thalamus divides into three bundles; the median one functions as the sepal trace and the laterals as the petal marginals. Next and alternate to the above, are given off the conjoint petal-stamen traces. The median portion of each trace functions as the petal midrib bundle and all along each of its margins are abstricted a row of four staminal bundles. These later emerge as five antipetalous groups each being clasped by the infolded petal margins. Next, five traces are given off sepal radii and these enter the filaments of the inner whorl of stamens without branching. The residual stele breaks up into the three dorsal carpellary traces and six ventral bundles, which again fuse and continue in the style. As the flower develops, the region of the thalamus between the groups of stamens grows out into a nectary which becomes prominent in the open flower.

The flowers of *Muntingia* and *Elaeocarpus* resemble those of *Tiliaceæ* in the origin, emergence and behaviour of the conjoint petal-stamen traces. The nectaries of *Elaeocarpus* differ from those of *Triumfetta* in being antisepalous outgrowths of the thalamus fed by strands from antipetalous staminal bundles.

***Bombax malabaricum* D.C.**

The flowers of *Bombax* are provided with a whorl of 8-10 bracteoles which form an epicalyx. The corolla is conspicuous, consisting of five asymmetrical petals which show contorted aestivation. The andræcium consists of 75 stamens placed in three series. There are five antipetalous groups of 12 stamens each; inner to these there is a ring of 10 stamens; the innermost series consists of five stamens whose filaments and anthers are much larger than those of the outer series. These

are described as "double stamens" (Gamble, 1935). The ovary is five-carpellary, syncarpous, five-locular and terminates in a long style with five stigmatic lobes. Numerous ovules are seen in two rows in each loculus on axile placentæ.

The pedicel is woody and shows a closed ring of vascular bundles which undergo secondary thickening due to the activity of a cambium (Fig. 83). Traces for the bracteoles are the first to be given off and then the traces for the sepals (Fig. 84). Higher up, the receptacular stele shows two zones, an inner ring of bundles for the gynoecium and an outer five-angled hollow cylindrical zone (Fig. 86). A little above, the outer ring breaks up into five V-shaped parts which have their angles pointing outwards (Fig. 87). These represent the common traces for the petals and stamens. Each trace then divides into three bundles. The median one, which functions as a petal trace, is larger and tangentially stretched and the lateral bundles which are the staminal traces are smaller and rounded in outline (Fig. 87). The petal traces bend outwards and form a ring near the circumference of the receptacle, while the five pairs of the antipetalous staminal traces form another ring a little to the inside. Now the bases of the five petals appear to the outside of the petal traces; the latter break up first into three and then into numerous smaller strands which traverse the petals (Fig. 88).

The pairs of staminal traces now undergo successive tangential divisions and each pair gives rise to 12 staminal bundles (Figs. 88 and 89). The pair of staminal bundles formed after each division bends outwards towards the base of the petal and makes room for the formation of another set of bundles. Though the staminal bundles formed appear nearly as large as the staminal traces themselves, the latter retain their individuality after these successive divisions. The staminal bundles enter the filaments of the groups of 12 antipetalous stamens. After a short interval, the staminal traces again divide in a tangential manner and give rise to a ring of 10 staminal bundles (Fig. 90). These get equally spaced and enter the filaments of the median ring of 10 stamens. After this, the two staminal traces derived from the parent trace come close together and traverse through the filaments of the innermost ring of five stamens running closely parallel to each other (Fig. 91). Hence a transverse section of their filament shows two vascular bundles (Fig. 93), while that of the outer stamens shows only one bundle as in normal stamens (Fig. 94). The double vascular supply seems to make them bigger than the outer stamens and these also bear one dithecal or two monothecous anthers. Thus there is full justification on anatomical grounds, for their being termed "double stamens".

As the base of the ovary gets demarcated, the inner ring of vascular bundles organises into the five dorsal traces and 10 ventral bundles. The dorsal traces are large and divide into a group of three-four bundles which run parallel to each other along the midribs of the carpels (Fig. 88). As the dorsal traces are originally situated on the same radii as the petal-stamen traces, the loculi are antipetalous in position, though as in *Pentapetes*, the asymmetrical growth of the petals disturbs this alignment. The common bundles formed by the fusion of the two ventral bundles at the base of the septum gives off the



FIGS. 83-94

FIGS. 83-94. Floral anatomy of *Bombax malabaricum*.—Fig. 83. Stele of pedicel. Fig. 84. Bracteole traces. Fig. 85. Stele after the separation of the bracteole traces. Fig. 86. Two zones of vascular tissue, outer for stamens and petals and the inner for the pistil. Fig. 87. Division of the conjoint petal-stamen traces; ovary shows the ventral and dorsal carpellary bundles. Fig. 88. Division of the petal bundles into three strands and the division of the staminal traces. Fig. 89. Repeated division of the staminal traces to form staminal bundles for the antipetalous groups of stamens. Fig. 90. Formation of bundles for the median ring of stamens. Fig. 91. Staminal traces for the last series of stamens. Fig. 92. Section of the style. Fig. 93. Section of the filament of the innermost group of stamens. Fig. 94. Section of the filament of the outer stamen. Fig. 92, $\times 12$. Rest, $\times 6$.

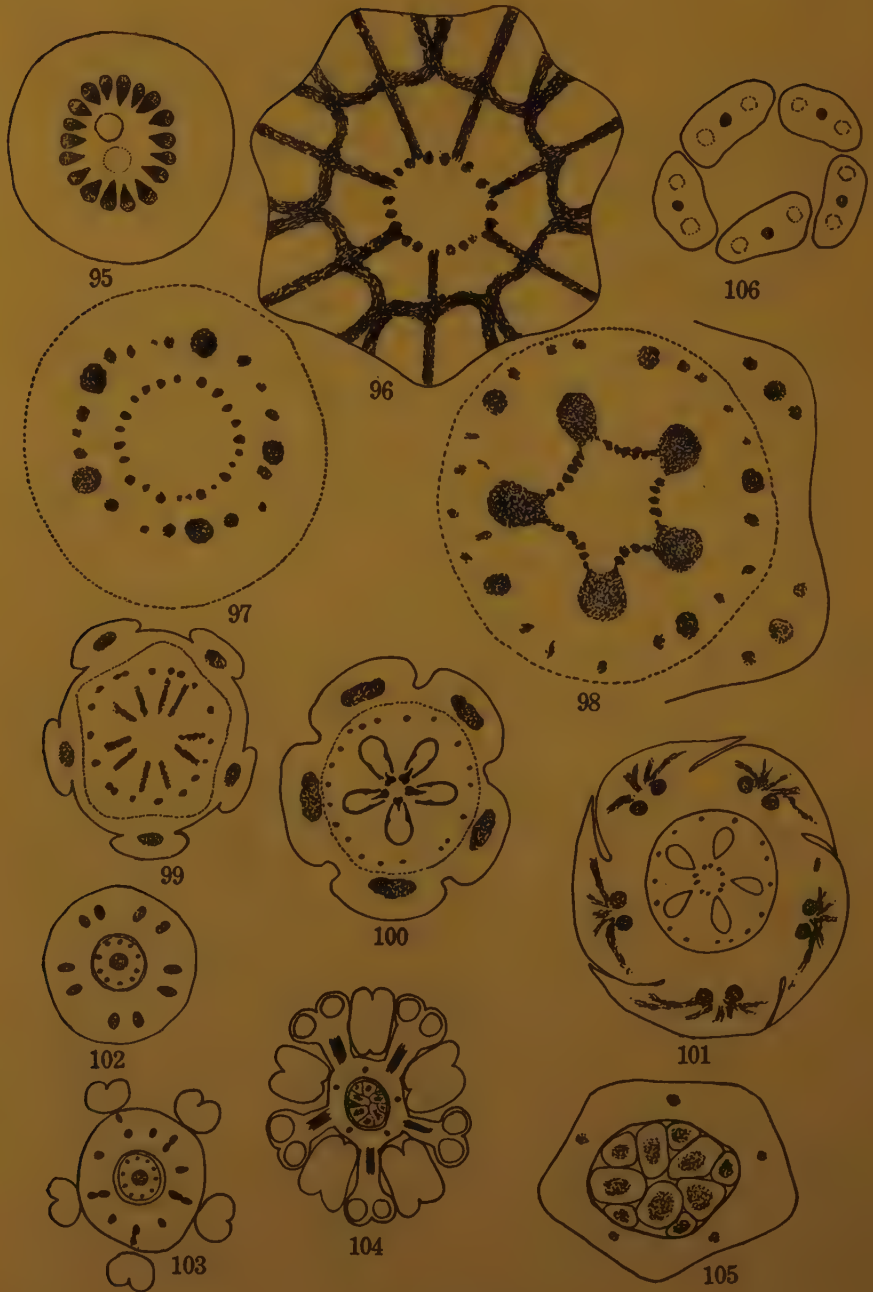
ovular traces. The septa do not fuse at the centre but leave a five-angled space. The style also shows a well marked stylar canal (Fig. 88). The latter is lined by radially elongated, richly protoplasmic cells. The vascular bundles of each carpel continue their course upwards in the style; each group enters and fades out in one of the stigmatic lobes (Fig. 92).

A study of the floral anatomy shows that the flower is tetracyclic. Warming (1932) described it as pentacyclic, mistaking the innermost series of double stamens to be the antisepalous whorl of unbranched stamens.

Malvaviscus arboreus Cav.

The flowers of *Malvaviscus arboreus* Cav. show the typical Malvaceous structure and are provided with an epicalyx of six-eight bracteoles. The andræcium consists of five alternating tiers of five stamens each, the staminal tube ending in five triangular teeth. The ovary shows one basal ovule in each of the five loculi and a long style which terminates in ten stigmatic branches.

The bracteole traces which are the first to be given off from the stele of the pedicel, branch into three strands each and these traverse as the midrib and laterals in each of the bracteoles (Fig. 96). The sepal traces which are the next to be given off, also branch in a similar manner (Fig. 98). The conjoint petal-stamen traces which are given off alternate to the sepal traces, form a ring near the circumference of the andræcium-corolla tube which begins to get demarcated from the ovary. A little above, the bases of the five petals appear to the outside of these traces (Fig. 99). Now each trace gets tangentially stretched, (Fig. 100), and becomes three-lobed, but it does not split up into three bundles as in *Bombax*. As the lobing becomes clearer, the median part breaks up into a number of strands which enter the petal, resulting in the separation of the laterally placed bundles which function as the staminal traces (Fig. 101). At the level of separation of the petals from the staminal tube, five pairs of these traces can be seen inner to the bases of petals (Fig. 102); higher up they get equally spaced. Bundles for the stamens are given off alternately from five of these traces. First, five of the traces divide tangentially forming staminal bundles for the first set of five stamens (Fig. 103). At about the level of emergence of these bundles into the filaments, the next set of staminal traces undergo division in a similar manner and this process



FIGS. 95-106

FIGS. 95-106. Floral anatomy of *Malvaviscus arboreus*.—Fig. 95. Stele of pedicel. Fig. 96. Origin and emergence of bracteole traces. Fig. 97. Stele after emergence of bracteole traces. Fig. 98. Bracteole bundles, sepal bundles and receptacular stele showing the formation of petal-stamen traces. Fig. 99. Bases of petals seen on the androecium-corolla tube; ventral bundles formed. Fig. 100. Conjoint petal-stamen traces enlarge; ovular traces given off. Fig. 101. Conjoint traces divide to form petal bundles and staminal traces. Fig. 102. Base of androecium tube with five pairs of staminal traces; base of style with ventral carpellary bundles forming a ring around the central zone of conducting tissue. Fig. 103. Formation of staminal bundles from five of the staminal traces. Fig. 104. Emergence of five of the staminal traces into the last series of stamens. Fig. 105. Top of the staminal tube, and the stylar branches. Fig. 106. Staminal teeth each showing a vascular bundle and two mucilage sacs. Fig. 95, $\times 30$ Fig. 96-105, $\times 15$; Fig. 106, $\times 45$.

continues till four tiers of stamens are formed. In the formation of the last series of stamens, the concerned traces bend out bodily into the filaments so that after their emergence the staminal tube is left only with the remaining five traces (Fig. 104). At the top, the staminal tube splits up into five staminodal teeth in each of which one of these traces terminates (Figs. 105 and 106). So, out of the 10 staminal traces, one set of five feeds three tiers of fertile stamens, while the second set feeds two tiers of stamens and terminates in the teeth of the staminal tube.

After the separation of the petal-stamen trunk cords, the receptacular stele is represented by a number of bundles placed in a ring. Out of these 10 bundles bend inwards and function as the marginal traces for the carpels (Fig. 99). No definite dorsal carpellary traces are organised, but all the remaining bundles which are more than five in number, traverse the fleshy ovary wall. The common bundle formed at the base of the septum gives off the single ovular trace and again splits up into the two component bundles. Towards the top of the ovary, the bundles traversing the ovary wall fade out but the marginal carpellary bundles continue their course forming a ring in the periphery of the style (Figs. 102 and 103). Higher up these fade out and the core of the style develops some conducting tissue (Fig. 103), which gradually increases in bulk. Towards the top of the style this tissue breaks up into 10 tracts each of which enters and fades out in one of the stigmatic branches. The latter emerge in two alternating whorls (Fig. 105).

Hibiscus solandra L. Herit and *H. micranthus* L.

The flowers of *Hibiscus solandra* L. Herit. and *H. micranthus* L. resemble those of *Malvaviscus arboreus* Cav. in the origin and behaviour of the bracteole, sepal and conjoint petal-stamen traces. In both, the 10 staminal traces get consumed in the formation of staminal bundles. In *H. solandra*, the staminal tube ends in a truncate manner while in *H. micranthus*, the tube terminates in five non-vascular teeth (Fig. 118). The differences noticed in the vascular plan of the ovary in these species, are incidental to the presence of numerous ovules and their axile placentation. The style in both species terminates in five stigmatic branches.



FIGS. 107-114. Floral anatomy of *Hibiscus solandra*.—Fig. 107. Stele of pedicel showing formation of bracteole traces. Fig. 108. Formation of sepal

traces; epicalyx seen at the outside. Fig. 109. Calyx separating from thalamus; formation of conjoint petal-stamen traces. Fig. 110. Corolla-andræcium tube separating from ovary. Fig. 111. Conjoint traces divided to form petal bundles and pairs of staminal traces. Fig. 112. Andræcium tube with five pairs of staminal traces. Fig. 113. Division of staminal traces to form staminal bundles. Fig. 114. Top of staminal tube which ends in a truncate manner, and style which is dividing into five stigmatic branches. Figs. 115-118. Floral anatomy of *Hibiscus micranthus*.—Fig. 115. T.s. flower bud showing bracteoles, calyx, andræcium-corolla tube and base of ovary which shows organisation of dorsal carpellary traces. Fig. 116. Ovary surrounded by andræcium-corolla tube. Fig. 117. Formation of petal bundles and staminal traces. Fig. 118. Styler branches surrounded by staminodal teeth. Figs. 119-122. Floral anatomy of *Abutilon indicum*. Fig. 119. T.s. flower bud showing andræcium-corolla tube in which the conjoint bundles have divided to form petal strands and staminal traces, and ovary. Fig. 120. T.s. pistil showing carpels and gynobasic style. Fig. 122. Staminal tube showing formation and emergence of staminal bundles. Figs. 107-109, $\times 15$; Figs. 110-113, $\times 10$; Fig. 114, $\times 50$; Figs. 115-118, $\times 10$; Fig. 119, $\times 10$; Fig. 120, $\times 15$; Fig. 122, $\times 15$.

Abutilon indicum G. Don.

The flowers of *Abutilon indicum* G. Don. do not show an epicalyx. The organisation of the sepal and conjoint petal-stamen and staminal traces is similar to that in other members of the family (Fig. 119). The gynæcium consists of numerous carpels which are free at base and united by the style which is gynobasic (Fig. 120). The style terminates in a large number of stigmatic branches which are equal to the number of carpels (Fig. 122). Each of the carpels shows two-three ovules on marginal placenta.

From the study of the floral anatomy, it is clear that the flowers of Malvaceæ are typically tetracyclic without any trace of the inner whorl of stamens, a point to which Saunders (1936) has already drawn attention. The teeth at the top of the staminal tube have been reported to represent the 'antesepalous unbranched stamens' (Willis, 1948), but this is just a speculation.

The above studies have shown that there is one character which is remarkably constant in the whole of the order, namely the origin and behaviour of the conjoint petal-stamen traces. Most or all of the stamens of a flower are derived by the chorosis of these traces. Still the anthers in some families are monothealous, while in others they are normal and ditheous. Wilson (1937) thinks that the 'half anthers' of Malvaceæ and Bombacaceæ are the result of the fusion of two adjacent male sporangia, the resulting stamens representing the penultimate segments of an ancient branch system. Saunders (1937) explains that in Sterculiaceæ and Tiliaceæ the staminal traces are first demarcated as such (*i.e.*, reach the determinate phase) and then undergo chorosis; so they are equivalent to whole traces and their chorosis results in the production of whole (ditheous) stamens. In Bombacaceæ and Malvaceæ, on the other hand, the determinate phase is not reached; hence the two staminal traces organised lateral to each petal trace are equivalent to half traces and the result of their chorosis is the production of half (monotheous) stamens. This explanation of 'halving' of the staminal trace seems to be teleological in order to explain the monotheous anther. Actually, the staminal traces in these families

also were found to divide into three bundles as in other families, but the apparent difference is caused by the lower level at which the branching occurs. The explanation of Saunders becomes further unconvincing because she applies it only to the primary and not to the secondary chorosis. Saunders remarks (1937, p. 106). "The initial halving is followed by numerous further divisions but since the determinate phase has by that time supervened, these later divisions do not cause a further fractionalisation but merely lead to a corresponding increase in the total number of half stamens."

DISCUSSION

Malvales is a very homogeneous order with not only well-defined morphological characters like stipulate leaves, regular, bisexual, hypogynous and polypetalous flowers, valvate calyx, multicarpellary syncarpous pistil with numerous ovules on axile placentæ, but also characteristic anatomical features like the "tile cells" in the vascular rays, mucilage sacs or canals, phloem stratified into fibrous and non-fibrous zones and the presence of glandular or stellate hairs. Various taxonomists like Warming (1932), Bentham and Hooker (1867), Rendle (1938), Hutchinson (1926) and Engler and Prantl (1928) have classified the order into three to eight families, but the arrangement of these is suggestive neither of affinities among the families nor of evolutionary tendencies.

On the basis of the anatomical studies of Chattaway, Edlin (1935) made what may be described as the first attempt at a natural classification of the order and discussed the phylogeny and interrelationships of the families. He excluded Chlænaceæ from the order due to the presence of imbricate calyx and amalgamated Scytopetalaceæ and Gonystylaceæ. Elæocarpaceæ is retained as a tribe of Tiliaceæ. He suggested the splitting of Sterculiaceæ into two families, Sterculiaceæ comprising the genera included in the tribe Sterculiæ and Buettneriaceæ including the remaining tribes. Another major alteration he suggested was the transference of the tribe Hibisceæ of Malvaceæ with about 23 genera, to Bombacaceæ. The following is his idea of evolution within the order, summarised in his own words (Edlin, 1935, p. 135): "The Scytopetalaceæ are the relics of those plants which once linked the Tiliaceæ with the more primitive groups such as the Dilleniaceæ and the Magnoliaceæ. The Tiliaceæ are the oldest, most primitive and the largest of the larger families. The Sterculiaceæ are a small and rather specialised group, derived directly from the Tiliaceæ. The Buettneriaceæ group of tribes were likewise derived from the Tiliaceæ and show considerable evolution from the polyandrous multistaminate staminodial forms to few staminate monadelphous staminodial forms (as *Cistanthera*) to few staminate monadelphous astaminodial forms (as *Waltheria*); this evolution is accompanied by a gradual change from an arborescent to a herbaceous habit. The Bombacaceæ are derived from Tiliaceæ along a different line and are characterised by the development of unilocular anthers and a connate or adnate andræcium. They lead on to the Malvaceæ which

are a highly advanced herbaceous family with a modified schizocarpous gynœcium."

In their exhaustive work on the anatomy of Dicotyledons, Metcalfe and Chalk (1950) do not give effect to Edlin's suggestions, except advocating the division of Sterculiaceæ into two major sub-families, the Sterculiæ and Buettneriæ. Elæocarpaceæ is retained as a separate family because they feel that "the anatomical structure of the members of this family is sufficiently distinct from that of Tiliaceæ to justify treating this family separately". Edlin's argument for amalgamation of the tribe Hibisceæ with Bombacaceæ is that they are primitive and transitional between the two families but resemble more the Bombacaceæ in their capsular fruits. Anatomically, no doubt, they stand separate from other tribes of Malvaceæ in their parenchyma but this distinction seems to have no significance "in view of the unusually wide range of variation within genera and even within some species" (Metcalfe and Chalk, 1950). It is interesting to note that the study of the seed anatomy of several members of Malvaceæ has led Reeves (1936) to a conclusion just the reverse of Edlin's, that the tribe contains genera like *Ingenhousia*, *Thespesia* and *Gossypium* which have attained a much higher level of phylogenetic development than members of other tribes. He justified the place given to it by Schuman (in Engler's classification) as the last among the tribes of Malvaceæ. The results of cytological studies by Davie (1933) also lend support to this view. The study of pollen grains shows that Hibisceæ possess the characteristic malvaceous type of multiporate spinescent grains which differ markedly from those of Bombacaceæ which are uniformly triporate and smooth walled. So the retention of Hibisceæ in Malvaceæ seems to accord best with the known facts.

Edlin (1935) remarked in connection with the andrœcium of Bombacaceæ, "the varied structure of a single feature in an otherwise homogeneous family seems deserving of special study which will throw light upon its œcological and phylogenetic import". What has been said of a single family can as well be said of the whole order, because while other floral characters remain fairly constant, the andrœcium both within the order as well as in the families and tribes, shows the greatest amount of variation. There are several types of stamens and staminodes in the order: antisepalous and antipetalous stamens; stamens with dithecal or monothecous or with two or more monothecous anthers; those formed without chorosis of the staminal trace and those formed after primary or secondary chorosis; stamens fed by a single bundle and those with two or three vascular bundles, etc. Similarly, all staminodes are not homologous. Within a family or even within a tribe, their morphology may vary. For example, the staminodes of *Klienhowia hospita* of the tribe Helicteræ, represent members of the inner whorl of andrœcium, while in *Helicteres isora* belonging to the same tribe, they are modified median stamens of the triplets of the outer whorl.

The study of floral anatomy, in addition to clarifying the position and morphology of these organs, has given an insight into the prob-

able lines of evolution within the order. Saunders (1937 and the works cited therein) made a thorough study of the floral anatomy of a number of Malvales but made no attempt at formulating any lines of evolution, probably because she was more deeply engrossed in her theory of Carpel Polymorphism.

In view of the wide range in the morphology of the stamens and staminodes, any observations made on the basis of their external features alone, are bound to be misleading and the phylogenetic considerations based on them erroneous. For example the flowers of *Triumfetta* and *Corchorus* (Tiliaceæ) and *Bombax* were described by Warming (1932) as pentacyclic due to the presence of two whorls of stamens but a study of their floral anatomy has shown that they are typically tetracyclic. In several books like Strasburger (1926) and Rendle (1938), the andrœcium of the order is described to be present in two whorls, of which the outer is either staminodal or suppressed and the inner is fertile and branching; floral anatomy has shown that the reverse is true in the majority of genera. Edlin (1935) remarked that only in exceptional cases obdiplostemony prevails in Malvales, but actually obdiplostemony is the rule and normal alternation an exception. Edlin (1935) considered Warming's theory of chorosis within the order as unsound since he thought that it was applicable only to Malvaceæ and not to Tiliaceæ. Such an error of judgment is also due to the reliance on the study of external features of the stamens. In Malvaceæ, the monotheous anthers make chorosis an obvious feature, but the ditheous anthers of Tiliaceæ obscure it. As already described, anatomically the stamens in both families are homologous since they are derived by secondary chorosis of the staminal traces. Edlin (1935) considered Scytopetalaceæ in which the numerous stamens are found in two series to be ancestral and derived from it the Tiliaceæ "with many stamens either free or united in antipetalous clusters in a single whorl or series." Sterculiaceæ and Buettneriaceæ "with few stamens and staminodes" are derived from Tiliaceæ. But anatomical studies have revealed that the flowers in Sterculiaceæ are predominantly pentacyclic while those of Tiliaceæ are tetracyclic. A flower of *Corchorus* with numerous stamens is actually more evolved than one of *Buettneria* with only five stamens and five staminodes, because the former is tetracyclic and the latter pentacyclic. So derivation of Sterculiaceæ from Tiliaceæ is not possible, while the reverse seems to be easy.

The writer's views are in perfect agreement with those of Edlin regarding the splitting of the order into two as done by Hutchinson (1926). Edlin (1935) considered Scytopetalaceæ to be ancestral family for Malvales but this is a small family with characters from which the important features of the remaining families of Malvales cannot be derived. In the opinion of the writer, Sterculiaceæ seems to be the most primitive family of Malvales. The characteristics of the family as given by Hutchinson (1926, p. 193) show a good range of variation. To these can be added the embryological characters like the presence of unilocular (*Fremontia*) or bilocular anthers, different types of pollen grains like spherical and smooth walled, spherical and spinescent,

ellipsoidal and lobed, triangular and oblatly flattened, etc. (Rao, 1950), and secretory and plasmodial type of anther tapetum (Rao, 1949 *a* and 1951). It is interesting to note that this family combines the important characteristics of the remaining families of Malvales, namely, the presence of stamens in two series and their arrangement in groups characteristic of Scytopetalaceæ, the gynandrophore, ditheous anthers, different types of pollen grains and secretory type of anther tapetum characteristic of Tiliaceæ and Elæocarpaceæ; the unilocular anthers and smooth walled pollen grains characteristic of Bombacaceæ; and the epicalyx, conspicuous corolla with contorted æstivation, unilocular anthers, spinescent pollen grains and plasmodial anther tapetum of Malvaceæ. Metcalfe and Chalk (1950) also point out that anatomically this family resembles Tiliaceæ on the one hand and Bombacaceæ and Malvaceæ on the other. So, Sterculiaceæ seems to represent a plexus of characters which may be looked upon as the starting points of special lines of advance which are stabilised in other families.

Edlin's argument for making the tribe Sterculiaceæ into a separate family is that it is the only tribe among Malvales in which both unisexuality and apetalý go together. He remarks "this separation would greatly simplify the sub-classification of the order Malvales. A definition which is broad enough to include them with the existing Sterculiaceæ besides being cumbersome to apply, is apt to include a few of the less typical Tiliaceæ and Bombacaceæ". But the same can be said of the tribe Helicteræ (*Klienhowia* and *Helicteres*) which have zygomorphic flowers, a character which is atypical for Malvales. If simplification should be the only criterion, one could advocate Bartling's suggestion (quoted from Wight, 1840), of making each of the tribes of Sterculiaceæ then recognised namely, Sterculiæ, Hermannieæ, Buettneriæ and Dombeyæ into families co-ordinate with the other families of Malvales. On the other hand, the study of floral anatomy has shown that in spite of the apparent diversity in the various tribes of Sterculiaceæ, there is a character which is fundamentally uniform, namely, the construction of the andræcium in $5_{(3)} + 5$ plan. This type of andræcial structure which is seen in four out of the five tribes of the family studied, including Sterculiæ, is not met with in any other family of Malvales. On the strength of this character, the writer feels that this should be retained as a single family.

In a number of genera of Sterculiaceæ, the flowers are constructed in the primitive pentacyclic plan with K, C, A in two whorls and G, which are often raised on a gynandrophore. The outer whorl of stamens which are antipetalous have traces conjoint with those of petals. After getting demarcated, they divide in a characteristic manner into three each, while the traces for the inner whorl pass on unbranched. Such a three-bundle trace is seen in a few families like Magnoliaceæ, Lauraceæ and Musaceæ and is regarded as primitive and all other types as derived (Eames, 1931). In the Dombeyæ, Buettneriæ and *Klienhowia*, the inner whorl is staminodal, but in *Sterculia* both whorls are fertile, though traces for the inner whorl do not branch. So it is evident that in the ancestral condition both whorls of stamens were fertile. The polyandrous stamens and apocarpous

pistil of *Sterculia* also show that its flower is nearer to the ancestral type, but it cannot be considered to be directly ancestral since reduction is already apparent in it, in its apetalous condition. In *Fremontia*, the andræcium is described by Saunders (1937, p. 115) as consisting of five 'antisepalous' stamens each with three vascular bundles in the filament and two irregularly shaped unilocular anthers and no separate staminodes. The lateral bundles of each group of three are derived by splitting of the 'antisepalous' staminal traces, while the median one is the unbranched alternisepalous trace. *Fremontia*, as Saunders observed, is exceptional in that it is the 'antisepalous' staminal traces which are branched and fertile and the alternisepalous traces which are unbranched and sterile. The branching of the antisepalous traces shows that like the antipetalous traces of other tribes, these also branched in the ancestral condition and fed fertile stamens. In *Fremontia* only two bundles are formed as a result of branching; probably the median one remained fused with the sepal trace as usually happens in the branching of the antipetalous traces in other members, e.g., *Triumfetta rhomboidea*, Bombacaceæ and Malvaceæ. The branching of the staminodal traces in *Pterospermum acerifolium* (Rao, 1949 b) may also be reminiscent of the ancestral condition.

So the ancestral type of flower for Malvales can be supposed to show the following features: epicalyx present; calyx valvate; corolla contorted or imbricate; two whorls of obdiplostemonous stamens, of which the outer has traces conjoint with those of petals; both sets of traces are three-bundled and feed fertile stamens; gynandrophore present; pistil of five separate carpels, each with many ovules on marginal placenta. From such a type evolution proceeded resulting in cohesion, adnation, reduction or multiplication of members by chorosis in the andræcium; syncarpy and tendency to perigyny due to reduction in the gynandrophore and further condensation of the thalamus; reduction in the number of carpels or their multiplication due to chorosis as in Maloeeæ of Malvaceæ. These lines are evident both within the families and tribes as also within the whole order. It is interesting to find, as Warming once suggested, that chorosis has played an important part in the evolution within the order, though there is no justification to regard, as he did, the flowers with a few floral parts to be more primitive than those with numerous.

Within the family Sterculiaceæ, the andræcium shows evolution along lines of cohesion and reduction. In *Sterculia*, it consists of $5_{(3)} + 5$ stamens members of both whorls being fertile. In *Dombeya*æ, *Klienhowia* and *Abroma* it is $5_{(3)} + 5$, the inner whorl being staminodal. In *Helicteres*, it is $5_{(3)}$, the inner whorl being completely suppressed; the median members of the triplets are also staminodal. In *Buetneria* it becomes $5 + 5$, the inner being staminodal; this condition is derived by non-branching of the outer staminal traces. In *Melochia* and *Waltheria*, the flowers become tetracyclic due to the suppression of the inner whorl and show only five antipetalous stamens. In *Sterculia* alone the stamens are free. In all others they unite into a tube at their base. Coincident with the evolution in andræcium, there

is also reduction or suppression of gynandrophore, syncarpy or reduction in the number of carpels to one as in *Waltheria*.

The andræcium of *Scytopetalum tieghemii* Hutch. et Dalz.,* is described by Edlin (1935, p. 134) as follows: "There are very numerous stamens slightly united in clusters at their bases, these clusters being arranged in whorls or series on the disc.... In the majority of flowers it is reduced to a circle or a pair of concentric circles. Where two such circles occur, it is usual for the staminiferous points on the outer circle to alternate with the insertion of petals; the staminiferous points on the inner circle likewise alternate with those of the outer." From this it is evident that there are two whorls of fertile stamens, which appear to be derived by secondary chorosis of both sets of staminal traces of the ancestral type of flower. So *Scytopetalaceæ* seems to have evolved along a line in which both whorls of stamens remained fertile and underwent chorosis.

In *Tiliaceæ*, the flowers become tetracyclic due to the suppression of the inner whorl of stamens. The traces for the outer whorl which are conjoint with those of petals as in *Sterculiaceæ*, split primarily into three bundles, after attaining the 'determinate phase'. In *Triumfetta* and probably in other members with the zone of glandular hairs inner to the petal bases (staminodal nectary), the median bundles remain adnate to the petal traces and become non-functional and only the laterals undergo secondary chorosis. In others like *Corchorus*, all the three bundles formed after primary chorosis undergo branching to form a large number of staminal bundles.

Evolution of *Bombacaceæ* and *Malvaceæ* seems to have proceeded along a different line but one already suggested in *Sterculiaceæ* and *Tiliaceæ*, namely, the suppression of the inner whorl of stamens and adnation of the median bundles of the triplets of the outer whorl of staminal traces to the petal trace and its consequent sterility. In *Bombax* and also in *Durio zibethinus* and *Adansonia digitata* (Saunders, 1937, pp. 111 and 113), the petal-stamen trunk cord splits up into three bundles before the determinate phase is reached. The central bundle which represents the petal trace to which the median bundle of staminal trace remains adnate, exhausts itself in the formation of petal strands and only the laterals remain functional and form numerous staminal bundles by secondary chorosis. In *Bombax*, the division of these bundles occurs in a simultaneous manner each time. Ultimately the pair of parent traces enter the filament of the double stamen. There is no trace of the inner staminal whorl except perhaps in the antipetalous position of the carpels.

In *Bombacaceæ*, the staminal tube is not a conspicuous feature as in *Malvaceæ*. The repeated chorosis of the staminal traces results in great congestion of the stamens. This can be relieved either by reduction in the number of stamens or by their emergence at different heights on an elongated staminal tube. The first method is seen in

* The material of *Scytopetalaceæ* was not available to the writer. So the conclusions are based on the description of the andræcium given by Edlin.

some genera like *Eriodendron* in which there are only five antipetalous stamens and the second method in the whole of Malvaceæ. In this connection, the floral anatomy of *Eriodendron anfractuosum* is interesting. According to Saunders (1937, p. 112) the staminal traces are conjoint with those of petals as in other Malvales. The organisation of the two staminal traces lateral to the petal trace occurs as in other genera of Bombacaceæ and Malvaceæ, but out of the two traces, only one divides and the resultant pair of bundles together with the undivided trace enter a filament so that there are three bundles in each stamen (as in *Fremontia*). Sometimes the two staminal traces traverse the filament undivided in which case the stamens resemble the double stamens of *Bombax*. The division of only five out of the 10 staminal traces is interesting as it definitely points towards what occurs in the whole of Malvaceæ. In this family, after the organisation of the staminal traces lateral to the petal trace as in Bombacaceæ, division occurs repeatedly in five out of the ten traces in an alternate manner, the staminal bundles so formed emerging at various heights in the staminal tube. So if in *Eriodendron*, the branching of the staminal traces were to continue without stopping after the first time, we get the andrœcium typical of Malvaceæ, which according to Hutchinson (1926) "is a very natural group representing a fixed type of Tiliales and whence little or no further evolution has progressed". Due to the low level at which the division of the petal-stamen traces occurs, the stamens appear to be adnate to the corolla and a sort of perigyny is also seen.

The behaviour of the petal-stamen traces in different families is represented in Fig. 123.



FIG. 123. A diagrammatic representation of the behaviour of the conjoint petal-stamen traces seen in the different genera of Malvales. *a*, Dombeyæ; *b*, *Helicteres*; *c*, *Corchorus*; *d*, *Triumfetta*; *e*, *Bombax*; *f*, Malvaceæ. Petal trace (Pt) and staminodal bundle chequered; staminal trace (St) dotted; arrows indicate secondary splitting of staminal bundles.

In addition to the above which may be described as the main line of evolution, there is an offshoot. As Saunders (1937) described, *Fremontia* is atypical not only for Sterculiaceæ but for the whole of Malvales, since in this the antisepalous traces undergo chorosis and feed fertile stamens, while the antipetalous traces remain unbranched and sterile. This tendency for the chorosis of the antisepalous traces is also seen in a few plants like *Tilia americana* (Saunders, 1937, p. 121). This side line of evolution has apparently led to a blind alley.

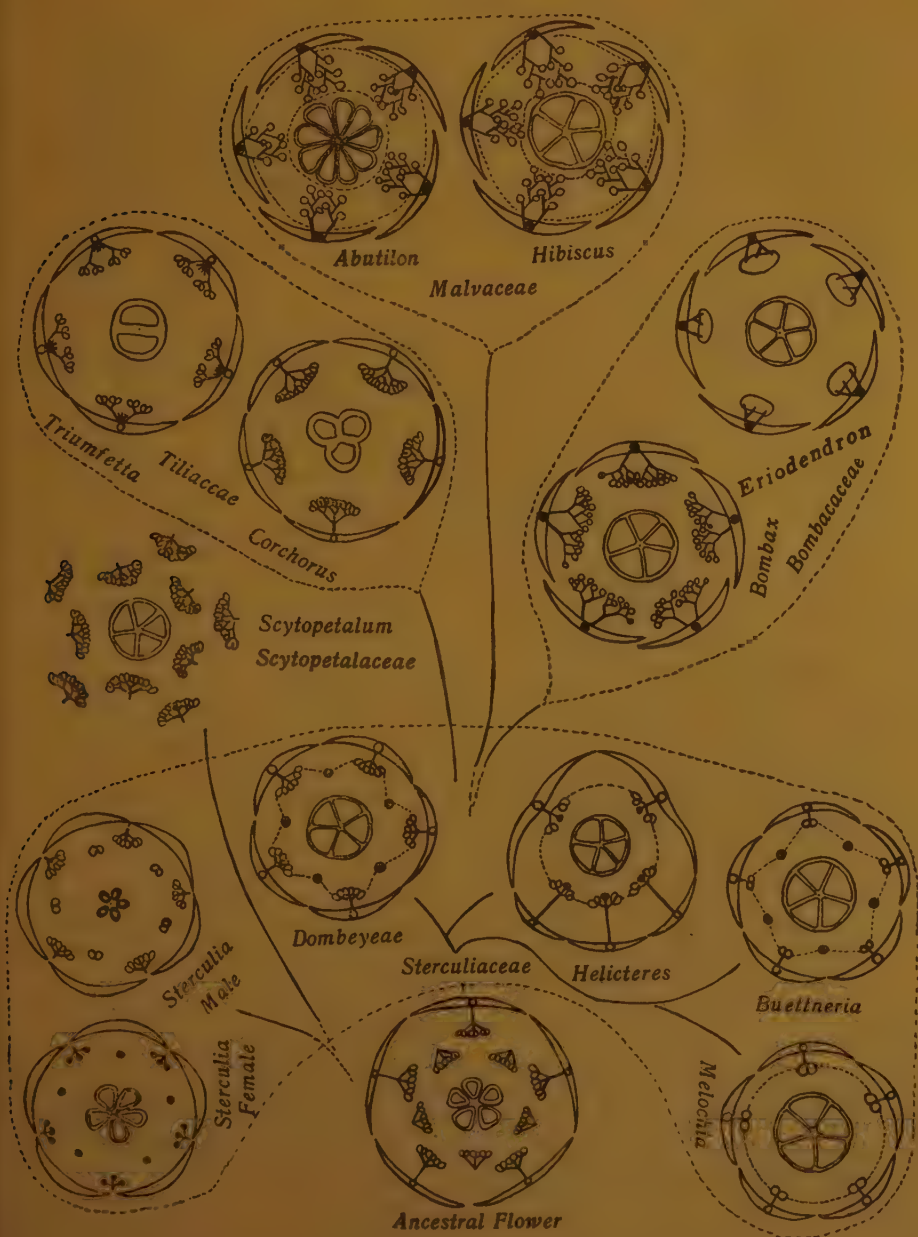


FIG. 124. Diagrammatic representation of the proposed lines of evolution within Malvales. Staminal bundles represented by black circles.

SUMMARY

The floral anatomy of *Sterculia foetida* L., *Klienhowia hospita* L., *Abroma augusta* L., *Buettneria herbacea* Roxb., *Melochia corchorifolia* L., and *Waltheria indica* L. of Sterculiaceæ; *Triumfetta rhomboidea* Jacq., *T. rotundifolia* Lam., and *Corchorus acutangulus* Lam. of Tiliaceæ; *Muntingia calabura* L. and *Elæocarpus robustus* Roxb. of Elæocarpaceæ; *Bombax malabaricum* D.C. of Bombacaceæ; *Malvaviscus arboreus* Cav., *Hibiscus solandra* L. Herit., *H. micranthus* L., and *Abutilon indicum* D. Don. of Malvaceæ is studied and on the basis of the findings, the affinities and evolutionary tendencies among the families included in the order are discussed.

Due to the presence of obdiplostemony and a conjoint petal-stamen trace and the uniformity in its behaviour, a common ancestry is presumed for all the families of the order. On account of the predominance of pentacyclic flowers and apocarpy and a number of synthetic morphological, anatomical and embryological characters, Sterculiaceæ is considered to stand nearest to the ancestral type of flowers, from which all other families are derived. In the ancestral flower, two whorls of fertile stamens are supposed to be present, the traces for both of which divide into three each as commonly occurs in the outer whorl of staminal traces in Sterculiaceæ. Scytometalaceæ is derived from such a type by chorosis in both whorls, the resultant bundles feeding fertile stamens. In Tiliaceæ and Elæocarpaceæ, the inner whorl of stamens is usually suppressed and the numerous stamens are the result of secondary chorosis of the outer whorl of staminal traces. In some genera like *Triumfetta*, the median bundle formed after primary chorosis remains adnate to petal trace and feeds only a staminodal nectary, while in others (like *Corchorus*) all the three bundles branch further and feed fertile stamens. In Bombacaceæ and Malvaceæ, the flowers are typically tetracyclic due to the suppression of the inner staminal whorl. The conjoint traces split into three bundles before the determinate phase. Consequently the median staminal trace remains adnate to petal trace and becomes non-functional, while the laterals undergo chorosis. In Bombacaceæ, the division of the traces occurs simultaneously each time, while in Malvaceæ five out of the ten traces undergo secondary chorosis alternately and the staminal bundles emerge at different levels on the elongated staminal tube.

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LITERATURE CITED

- BENTHAM, G. AND HOOKER, J. D. 1867. *Genera Plantarum*. London.
 DAVIE, J. H. 1933. Cytological studies in Malvaceæ and allied families. *Jour. Genet.* 28: 33-67.

- EAMES, A. J. 1931. The vascular anatomy of the flower with refutation of the theory of carpel polymorphism. *Amer. Jour. Bot.* 18: 147-188.
- EDLIN, H. L. 1935. A critical revision of certain taxonomic groups of the Malvales. *New Phyt.* 34: 1-20 and 122-143.
- ENGELER, A. AND PRANTL, K. 1928. *Natürliche Pflanzenfamilien*. 2 Auflage.
- GAMBLE, G. S. 1935. *Flora of the Madras Presidency*. London.
- GAZET DU CHATTLIER GERARD. 1938. Sur la structure de l'androcee des Sterculiacees. *Comt. Rend.* 1140-1141.
- , 1940. La structure florale des Sterculiacees. *Comt. Rend.* 210: 57-59.
- HURCHINSON, J. 1926. *Families of Flowering Plants*. Vol. I. London.
- METCALFE, C. R. AND CHALK, L. 1950. *Anatomy of Dicotyledons*. Vol. I. Oxford.
- RAO, C. V. 1949 *a*. Contributions to the embryology of Sterculiaceæ—I. *Jour. Ind. Bot. Soc.* 27: 180-197.
- , 1949 *b*. Floral anatomy of some Sterculiaceæ with special reference to the position of the stamens. *Jour. Ind. Bot. Soc.* 28: 237-245.
- , 1950. Pollen grains of Sterculiaceæ. *Jour. Ind. Bot. Soc.* 29: 130-137.
- , 1951. Contributions to the embryology of Sterculiaceæ—III. *Melochia corchorifolia* L. *Jour. Ind. Bot. Soc.* 30: 122-131.
- REEVES, R. G. 1936. Comparative anatomy of seeds of cottons and other Malvaceous plants. *Amer. Jour. Bot.* 23: 291-296 and 394-405.
- RENDLE, A. B. 1938. *Classification of Flowering Plants*. Vol. II. Cambridge.
- SAUNDERS, E. R. 1937. *Floral Morphology*. Vol. I. London.
- STRASBURGER, E. 1926. *Text-Book of Botany*. English Translation. London.
- WARMING, E. 1932. *A Handbook of Systematic Botany*. English Translation by M. C. Potter. London.
- WIGHT, R. 1840. *Illustrations of Indian Botany*. Madras.
- WILLIS, J. C. 1948. *A Dictionary of Flowering Plants and Ferns*. Cambridge.
- WILSON, C. L. 1937. The phylogeny of stamen. *Amer. Jour. Bot.* 24: 686-699.

THE FIELD METHOD IN THE STUDY OF PLANT COMMUNITIES

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ALTHOUGH, India provides unique opportunities and is in a favourable position to lead the world in forest biological research, there has been little advance in ecological studies in this country during the last 30 years (Champion, 1937; Hewetson, 1951). This is partly due to greater emphasis on other branches of forestry and botany and partly due to lack of suitable literature and simple techniques and methods for ecological survey of our vegetation.

Clements' (1905) work on research methods in ecology has long been out of print and Tansley and Chipp's book (1926) in which Troup and Stamp included chapters on Indian and Burmese ecology has become out of date and contains methods mostly suited to the study of rain forests. In recent years a number of books have appeared on the subject, of which those by Tansley (1926), McClean and Cook (1946), Oosting (1938) and Gates (1950) describe a number of field methods, but these relate chiefly to temperate forests and grassland communities. Milne (1948) in Africa, and Morrison, Hoyer and Hope-Simpson (1949) in Sudan have, however, developed methods in the survey of tropical vegetation. These methods are similar to those followed by Swedish and Finnish forest departments in their national surveys of forests. Although these methods, which I used during my field studies in U.K. and Europe (Puri, 1950 *b* and 1950 *d*), and also in this country (Puri, 1950 *c*, 1951) are now well known in other countries, they have not been described in detail in any single work and are not easily available to botanical workers or those interested in the study of vegetation in this country. It is, therefore, considered desirable that a suitable field method be described in detail and brought within the reach of students of Indian vegetation.

In my field studies in different types of Indian vegetation during the last three years, the European methods were used (Puri, 1950 *a*, 1950 *c*) with various modifications to suit local conditions of topography, geology, aspect, slope, density of the forest crop, and its type. This has resulted in the formulation of a new method which combines the essentials of all known methods and has been found to be the most suitable for use in this country.

The chief merit of the method is its simplicity and its application in forestry, agriculture and grassland studies. It can be applied in forestry to management, silviculture, valuation, protection, erosion, soil conservation or simple vegetational surveys. It is statistically planned and provides quantitative data to compile a detailed vegetation map, which is not only useful in determining soil fertility under

the prevailing systems of land use for agriculture or forestry, but is also useful in following the progress of regeneration and successional development of plant communities in a natural forest. It also finds application in the scientific exploitation of forests and being simple can be used by forest range officers with a little training. The method is particularly suitable for the study of weeds and observing changes in the quality of agricultural crops due to microclimatic or micro-edaphic variations. It is equally suited for the study of natural vegetation or plantations. In short, it can be applied to study place to place variations in the green covering of the earth and its relationship, if any, with the complex of environmental factors. The method is described below:—

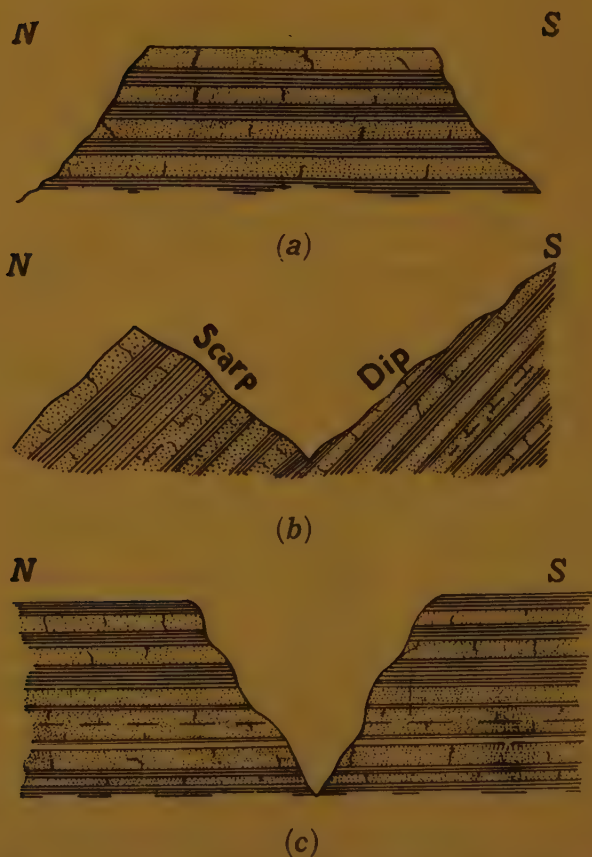
Transect method.—A transect is a line or a belt passing through the area to be studied. It cuts across the main topographical, geological and geomorphological features. Essentially, it is the forester's strip across the stand which is used in volume estimation (Robertson, 1927; Thomson, 1947; Watson, 1934; and Weislander, 1935). Finny (1947) calls it a "sampling unit". It may be a line or a belt across a plant community, or a rectangular unit in a stand of varying width—from a few feet to a couple of chains or more. The length of a transect is usually not fixed, but depends upon the nature of the study and composition and type of vegetation and its environment.

It is run in a particular direction. This is fixed after a thorough reconnaissance of the area with due regard to fertility gradients. As fertility lines in a forest are usually related with level, in hilly areas the transect is laid across the contours, which mark changes in temperature, rainfall and humidity and in certain cases also in soil conditions.

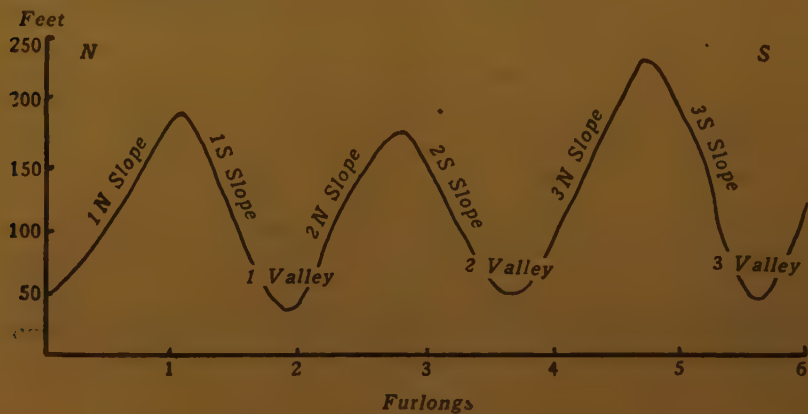
In some cases in the Himalayas, contour lines do not necessarily coincide with fertility lines, especially where the underlying rock strata instead of lying horizontally dip in one or the other direction. In such cases a transect should be laid parallel to the dip of the strata and across the scarp, covering both the dip and scarp slopes (Puri, 1950 *a*, 1950 *b*, 1950 *c*) (Fig. 1 *b*). In a horizontally stratified area forming a plateau or a valley in it a transect may be run from N to S as shown in Figs. 1 *a* and 1 *c*.

In still other cases overlying deposits, namely, alluvia, flood plains, moraines, volcanic lava, and mud flows or dykes may be present without any regard to contour lines and transect must necessarily run across these features of landscape, if differences due to these factors are to be properly assessed.

A transect in hilly areas must cover at least one topographic unit which consists of three valleys, three tops, three north slopes and three south slopes (Fig. 2). In gently sloping areas or those that are dead level the direction of the transect is usually N to S or NE-SW and the length of the transect may be a mile or two, so as to sample sufficient variations in forest crop and changes in the soil.



FIGS. 1 *a, b, c*. Diagram showing the arrangement and direction of strata in a plateau (*a*), in a plateau valley (*c*), and on valley sides in which strata dip towards N (*b*). A transect should be run N to S in all cases.



FIGS. 2. Diagram of a topographical unit

In crops managed under regular systems of management or in plantations, the length of the transect is usually longer than in primeval forest. The transect for successional studies is again longer than when the aim is to study only the progress of regeneration. In the latter case transect may be small and a rectangular plot.

A number of parallel running transects should be studied if detailed composition of vegetation with regard to yield of the crop, etc., is desired. However, for merely ecological studies of associations a couple of parallel running transects in typical areas have been considered sufficient by ecologists in other countries. In primeval or undisturbed forests results obtained by the study of one typical transect laid at a proper place may be representative of the area. In disturbed forests or those that are developed in regions with large variations in geology and geomorphology the number of transects should be at least three. Morrison, *et al.* (*loc. cit.*) in vegetation surveys of Sudan have been able to bring representative data by the study of a single transect.

Actual recording of vegetation is done in smaller units called quadrats, which in Finney's (*loc. cit.*) terminology are "recording units." These are either square or circular, and are of a convenient size, depending upon the type of vegetation one is studying. For recording trees, and shrubs circular quadrats of 18.6 ft. radius are convenient in thick forests. In open forests with little shrub layer, quadrats with a radius of 73.2 ft. may be used. In respect to acreage, the quadrat with 18.6 ft. radius is approximately 1/40th of an acre and the other has an area equal to approximately 1/10th of an acre. In double and many storeyed forests, where visibility in a line is small and where the ground layer is profusely developed, the radius of quadrats may have to be halved or even further reduced for the recording of vegetation.

The quadrats are studied on a transect at suitable intervals, care being taken that these do not overlap and same trees are not counted in two adjoining quadrats.

For ground flora communities and tree-seedling growth, small quadrats of one meter square or one yard square are studied in the larger tree quadrats. Depending upon the investigation in view, a number of ground flora quadrats are studied in a tree quadrat. In grassland communities, in the study of weeds and agricultural crops, the size of quadrats is nearly $\frac{1}{3}$ or $\frac{1}{2}$ of that used in recording ground flora species in a forest. In the study of other smaller forms of vegetation, e.g., mosses, liveworts and lichens, the size of the quadrat may not be more than one foot square.

The method outlined here has been advocated by foresters. For example, Lowdermilk (1927) suggested miliacre areas of 6.6 ft. square for counting regeneration. Kadambi's (1943) spot method consists of circular areas or spots of one chain radius for complete studies. The study of a larger number of quadrats of a smaller size is advantageous not only for convenience in recording, but it takes into account a far greater amount of variation. This method is more accurate statistically.

There has been a good deal of discussion on the methods of selection of transect and quadrats. For volume estimation surveys, Griffith's (1945-46) work in different types of forest in India and Finney's (1947-48) masterly discussion seem to show that random selection of transect and quadrats is best from statistical point of view. However, for biological considerations ecologists throughout the world have not strictly followed random sampling technique in the selection of lines for laying transects. In practice some bias is always shown in selecting a transect (see Morrison, *et al.*, *loc. cit.*). There are considerations either of the best composition of the community, and its more natural and primeval conditions, or general topographical and environmental considerations that limit the choice. Sometimes the accessibility of the area and convenience of work are also considered in selecting a line for study. Although, strict randomisation is usually not done in ecological work, the results obtained by such studies have been invariably found to be more representative. This is chiefly due to the fact that the line is laid perpendicular to fertility gradient and all variations in forest composition due to the fundamental environmental factors are sampled adequately along this line. The need of randomisation is great in highly disturbed forests, but generally ecological work for establishing the relationship between forest and environment is not encouraged in such situations. For ecological work virgin or little disturbed forest areas are selected. Some sort of randomisation is done in the selection of ground flora quadrats in a tree quadrat. But here too quite often the choice is limited, especially when the object is to sample only certain types of ground flora communities and to find out the causes that govern the growth and distribution of only these and associated types of seedling growth. In agricultural and grassland communities where the areas are small and easy to approach and recording is not difficult, strict randomisation may be done in selecting quadrats. Here the size of the quadrat and the number of the quadrats will also have to be fixed to get a complete picture of vegetation. Subject to these limitations, the technique of selection is not different from that used in volume estimation surveys and is in accordance with international ecological methods.

The most interesting and useful part of the transect study is the thoroughness with which the recording of vegetation and evaluation of environment are done in quadrats.

In a tree quadrat, all the trees of different species in various layers or strata are counted separately; and their diameter or girth taken at breast height. The number of poles and saplings is separately recorded. Felled, lopped, burnt or malformed trees are specially mentioned to indicate the human influences that the forest is subjected to. At the time of observation, the phenological conditions of the dominant species in the community are also recorded. In addition to the quantitative data, qualitative observations on cover, position of tree crown in relation to light intensity; sociability or gregariousness of the species, their stratification, their vitality, and periodicity (in the case of ground flora) are also made.

In ground flora quadrats the presence or absence of species, seedling growth, etc., is recorded by such terms as abundant (*a*), common (*c*), rare (*r*), present (+), and absent (—). In regeneration counts only established seedlings are mentioned, though recruitment is also indicated. These quadrats are laid at places where one meter square or about that size of patches of distinct ground flora communities with associated tree seedlings are found. It may be pointed out that single isolated plants of a species are not of any importance in indicating environmental conditions. For they may belong to ephemeral species or may be occasional, with low fidelity and low vitality and may not be truly representative of the locality. The study of distinct and compact ground flora communities in larger patches is therefore emphasised for ecological purposes (Pearsall, 1938; Puri, 1950 *d*).

In addition to the ground flora communities and seedling growth data on tree litter, humus, soil colour, texture, its visible micro-fauna (*e.g.*, worms, termites, insects, etc.) and micro-flora (*e.g.*, fungus growth, matted condition of the litter, etc.) is usually observed. The temperature of the air at breast height and at ground level and of the soil at the surface and subsoil (with earth thermometers) is measured to get some idea of the community climate, especially the humidity.

Samples of humus from top, 0 inch to six inches of the soil or from the rooted region of the seedling growth and ground flora communities are collected from the centre of the ground flora quadrats for detailed analysis according to the lines laid down by Griffith and Gupta (1947) at selected spots to study tree roots, and their distribution in the various horizons of the soil. Samples from different layers in well-developed soils, *e.g.*, podsols, brown earths, chernozems, laterites, etc., or from different depths (in azonal soils), are brought to the laboratory for determination of pH, organic matter, exchangeable calcium, exchangeable bases and nitrogen. Usually in azonal soils, samples are taken from 0 inch, 6 inches, 12 inches, 24 inches, 36 inches, 48 inches and 60 inches. In rare cases sample from the depth of 6 feet is taken.

The vegetational data is conveniently recorded in a field book* and it is analysed in field or in the laboratory in the following way:

The number of all the trees, saplings, shrubs, etc., in each quadrat are added up and percentage of each species is determined. This gives data for the density of the different species in a unit area (quadrat) and can be made into different density classes. The percentage of the total number of quadrats in which a species occurs gives frequency. Frequency occurrences are determined for all species in a transect separately or in all the transects studied and are conveniently grouped in Raunkiaer's (1934) five frequency classes (see Oosting, *loc. cit.*) as follows:

* This can be had from the Vasant Press, Dehra Dun.

Frequency class A = 1–20%
 B = 21–40%
 C = 41–60%
 D = 61–80%
 E = 81–100%

On the basis of 8,000 frequency percentages Raunkiaer found that his frequency class A included 53% of the species B 14%, C 9%, D 8% and E 16%. On this he propounded his following “law of frequency”.

$$A > B > C \begin{matrix} \leq \\ \geq \end{matrix} D < E$$

This law can be represented in the normal frequency diagram (Fig. 3).

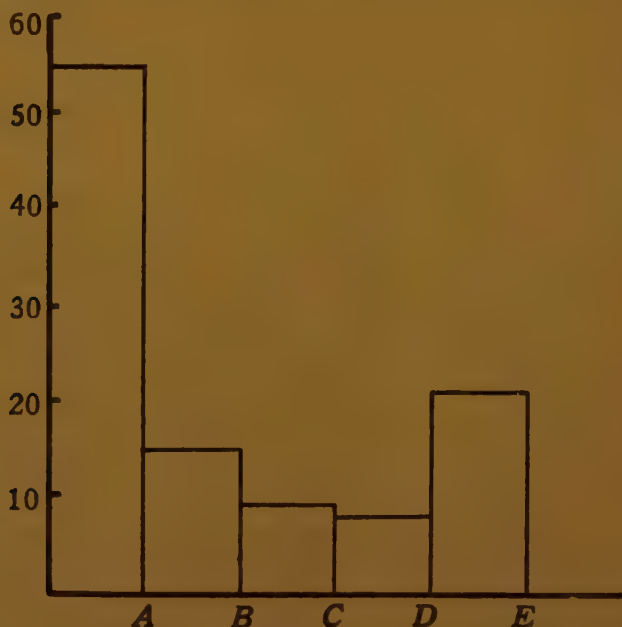


FIG. 3. Normal frequency diagram of Raunkiaer

After determining frequency classes A, B, C, D, E, the frequency diagrams are prepared and compared to Raunkiaer's normal frequency diagram.

In additoin to these, diameter or girth classes can be determined to give an idea of space and cover occupied by each species in a community. This data of density, frequency classes, etc., can be represented in phytographs (Fig. 4) for various plant communities. Phytographic representation of quantitative characters of plant communities

provides useful index for comparing two or more plant communities in a sere, or observing changes in the same plant community at some interval of time (see Rowe, 1949; Oosting, 1948). It also evaluates the effect of the prevailing systems of management or silviculture on the composition of forest communities.

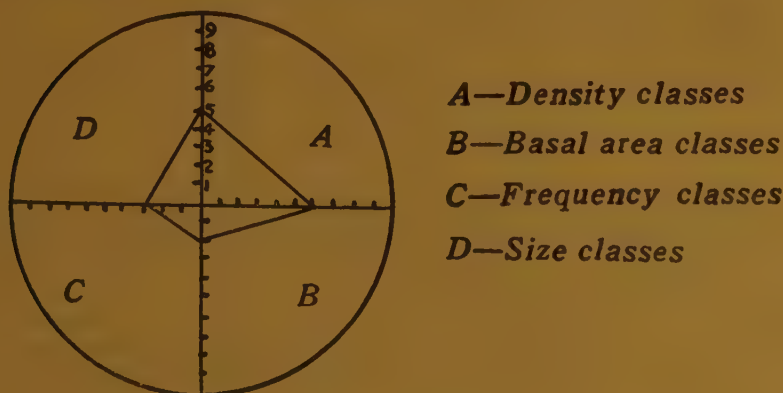


FIG. 4. A phytograph showing comparative density, frequency, basal area and size classes of a plant community.

The phytographs, frequency diagrams and qualitative data on periodicity, stratification, vitality, gregariousness, etc., give a detailed description of plant communities.

The relationship of plant communities with soil features is obtained by presenting the data in tabular forms with descending or ascending order or by means of graphs, bar diagrams or histograms. The author has employed these methods in his studies of English vegetation (Puri, 1950 *d*) and also in some studies conducted in this country (Puri, 1950 *c*; Puri and Gupta, 1951).

The relationship of plant communities with geological features is studied in field by noting the type of plants occurring on dip and scarp slopes and the data are represented in profile sections made to scale (Puri, 1949, 1950 *a* and 1950 *c*). Profile sections are also made showing the relationship of soil features with topography and plant communities.

The use of this method is recommended for working plans enumerations and other studies in the forest. The data on the composition of forest communities and their relationship to climate, soil, geology and biotic influences given for the divisions in working plans is usually very inadequate and it may be desirable to collect further data by this method for working out prescriptions of management and silviculture. The transect method in enumeration affords a wealth of useful data not only on the present condition of the crop, but the assessment of its dynamic relationships with the

soil, succession of plant communities and the ecological nature of the future crops is also made. So far as I know, no data have been collected in any state forests evaluating the effects of the main silvicultural and management systems on the ecological changes in the crop. These can be collected by the transect method. This method is most suitable for teaching ecology in Indian Universities and it is hoped that it will be followed in research work also. The author will be grateful if other workers send him their suggestions and criticism of the field method described so that it can be improved and perfected for general use in this country.

SUMMARY

The transect method in the study of plant communities is described. The methods of laying a transect and charting quadrats are given. The ways of collecting and analysing vegetational and environmental data are described in detail and the methods of their representation and correlation with each other are enumerated. The chief merits of this method are its simplicity and the great amount of information it provides at a relatively low cost. The applicability of this method to the study of every type of vegetation is shown.

LITERATURE CITED

- BROWNE, F. G. 1936. Milliacre surveys. *Malayan Forester*, 5: 177-183.
- CHAMPION, H. G. 1937. The need for scientific study of India's climax vegetation. *Presid. Add. Ind. Sci. Cong. Abstract in Curr. Sci.* 5: 379.
- CLEMENTS, F. E. 1905. *Research methods in ecology*. Washington.
- FINNEY, D. J. 1947. Volume estimation of standing timber by sampling. *Forestry*, 21: 179-203.
- , 1948. Random and systematic sampling in timber surveys. *Forestry*, 22: 64-99.
- GATES, F. G. 1950. *Manual of Field Ecology*. New York.
- GRIFFITH, A. L. 1945-46. The efficiency of enumerations, I-XIV. *Indian Forest Leaflets*, Nos. 83-93.
- AND GUPTA, R. S. 1947. The recording of soil and site characteristics in the field. *Ind. For. Bull.* No. 135.
- HEWETSON, C. E. 1951. Ecology of *Tectona grandis*. *Mad. For. Coll. Mag.* 27: 101-108.
- KADAMBI, K. 1943. Valuation survey by spot method. *Ind. For.* 69: 107-112.
- KING, H. C. 1934. The limitations of forest reconnaissance surveys. *Ind. For.* 60: 545-550.
- LOWDERMILK, W. C. 1927. A method for rapid survey of vegetation. *Journ. For.* 25: 181-185.
- MC. CLEAN, R. C. AND W. R. I. COOK. 1946. *Practical field ecology*. London.
- MILNE, G. 1947. A soil reconnaissance journey through parts of Tanganyika territory, Dec. 1935 to Feb. 1936. *Journ. Eco.* 35: 1-92.
- MORRISON, C. G. T., A. C. HOYLE AND J. F. HOPE-SIMPSON. 1948. Tropical soil-vegetation catenas and mosaics. A study in the south-western part of the Anglo-Egyptian Sudan. *Journ. Eco.* 36: 1-84.
- OSHTING, H. J. 1948. *The study of plant communities*. California.

- PEARSALL, W. H. 1938. The soil complex in relation to plant communities. II. Woodland soils. *Journ. Eco.* 26: 194-209.
- PURI, G. S. 1949. Physical geology and forest distribution. *Sci. and Culture*. 15: 183-186.
- , 1950 a. Distribution of conifers in the Kulu Himalayas with special reference to geology. *Ind. For.* 76: 144-153.
- , 1950 b. Surface geology, vegetation and plant succession. *Ind. For.* 76: 199-209, 254-262.
- , 1950 c. Soil pH and forest communities in the sal (*Shorea robusta*) forests of the Dehra Dun Valley, U.P., India. *Ind. For.* 76: 292-309.
- , 1950 d. The ecology of the humus layer in some English forests. *Ind. For.* 76: 418-427, 453-466.
- AND A. C. GUPTA. 1951. The Himalayan conifers. II. The ecology of humus in conifer forests of the Kulu Himalayas. *Ind. For.* 77: 55-63, 124-129.
- RAUNKIAER, C. 1934. The life forms of plants and statistical plant geography; being the collected papers of C. Raunkiaer. Oxford.
- ROBERTSON, W. M. 1927. The line-plot system, its use and application. *Journ. For.* 25: 157-163.
- ROWE, J. S. 1947. Characterisation and comparison of forest stands by means of phytographs. *Silviculture research note* No. 93.
- TANSLEY, A. C. 1926. *Practical plant ecology*. 2nd Edition. London.
- AND F. T. CHIPP. 1926. *Aims and methods in the study of vegetation*. Oxford.
- THOMSON, A. P. 1947. The National forest survey in New-Zealand. *Proc. fifth Empire Forestry Conference*. London.
- WATSON, J. G. 1934. The limitations of forest reconnaissance surveys. *Ind. For.* 60: 144-150.
- WIESLANDER, A. E. 1935. First steps of the forest survey in California. *Journ. For.* 33: 877-884.

REVIEWS

Carbon Dioxide Fixation and Photosynthesis. BY J. F. DANIELLI, and R. BROWN. Published for the Company of Biologists at the University Press, Cambridge, 1951.

This volume, which is the fifth in the series brought out by the Company of Biologists, is based on a number of papers originally read at a Symposium organized by the Society for Experimental Biology at Sheffield in July 1950.

The titles of the papers best describe the contents of the volume: "Carbon dioxide fixation in animal tissues" by H. A. Krebs, "A consideration of some reactions involving carbon dioxide fixation" by H. G. Wood, "Biosynthesis of dicarboxylic and tricarboxylic acids by carbon dioxide fixation," by S. Ochoa, "Oxalacetic decarboxylase and carbon dioxide assimilation in bacteria," by D. Herbert, "Carbon dioxide fixation and acid synthesis in Crassulacean acid metabolism," by M. Thomas, "Assimilation by green leaves with stomatal control eliminated," by O. V. S. Heath, "Some physical aspects of assimilation and transpiration," by H. L. Penman and R. K. Schofield, "The photochemical formation and reactions of atoms and radicals in aqueous systems," by M. G. Evans and N. Uri, "Photochemical oxidation-reduction process in aqueous systems," by J. Weiss, "Resonance transfer of energy between molecules," by E. J. Bowen, "the physical background of photosynthesis," by J. Franck, "The maximum efficiency of photosynthesis," by M. S. Nishimura, C. P. Whittingham and R. Emerson, "Photo-induced interactions in metabolism of green plant cells," by B. Kok, "Reduction by chloroplasts," by R. Hill, "The photochemical reduction process in photosynthesis," by C. S. French and H. W. Milner, "The reducing action of light in photosynthesis," by E. C. Wassink, "Intermediates in photosynthesis: formation and transformation of phosphoglyceric acid," by H. Gaffron, E. W. Fager and J. L. Rosenberg, "Carbon dioxide assimilation in plants," by M. Calvin, J. A. Bassham, A. A. Benson, V. H. Lynch, C. Ouellet, L. Schou, W. Stepka and N. E. Tolbert, "Extensions of photosynthetic experimentation," by O. Warburg, D. Burk and A. L. Schade, "Three-vessel and one-vessel manometric techniques for measuring CO_2 and O_2 gas exchanges in respiration and photosynthesis," by D. Burk, A. L. Schade, J. Hunter and O. Warburg, and "The use of ' CO_2 -buffers' in manometric measurements of cell metabolism," by H. A. Krebs.

All the papers are by well-known experts and take one right to the frontiers of the science of carbon assimilation. The book should prove an invaluable aid to all engaged in research in this field.

A. C. J.

The Genetics of Micro-Organisms. BY D. G. CATCHESIDE. Published by Sir Issac Pitman & Sons Ltd., London, 1951. Pp. vii+223. Price 21 *sh.*

Micro-organisms, particularly fungi, have proved extremely useful material for genetic study for three reasons. Firstly, their life-cycle is completed very rapidly and they are easily cultivable on chemically known media under precise environmental conditions. Secondly, they provide possibility of analysing, in a tetrad, the products of any one meiosis. Thirdly, the genetic investigations in this field have not only been in respect of morphological characters but also biochemical characters, leading to a synthesis of biochemistry and physiology with genetics which is so essential to an understanding of the mysteries of the living cell. Very striking progress has been achieved in this field in recent years and geneticists will feel deeply indebted for the present authoritative treatise on the subject from so distinguished an authority as Professor Catcheside.

The book is based on a course of lectures devised for biochemists specializing in the microbial aspects of the subject, but the author has traversed a very wide field including fungi, yeasts, protozoa, bacteria and viruses and has given a concise account of the essential facts relating to our present knowledge of the genetics of micro-organisms, useful at once to the teacher, undergraduate and research worker.

Chapter I introduces the subject. Chapters II to IV are devoted to genetics of fungi and occupy nearly half of the space in the book. Most of the genetical work on fungi is on *Neurospora crassa* which occupies the same position among micro-organisms as *Drosophila* among animals and maize among the higher plants. Chapter II deals with gene segregation in ordered and unordered tetrads, mimic mutants, multiple allelism, etc. Chapter III includes a thorough discussion of the now classical biochemical mutants of *Neurospora* and Chapter IV deals with adaptation and mutation in *Neurospora*. Most of the induced mutations are of a more or less destructive nature. Chapter V gives a very lucid survey of the sexual reproductive systems and an instructive discussion of diecism, relative sexuality, compatibility genes and parasitism. Professor Catcheside points out that resistance of a host to a given pathogenic race of a fungus seems, as a rule, to be dominant to susceptibility and that avirulence of a fungus is dominant to virulence in respect of given host. He considers that for dominance a pair of substances 'H' and 'P' (corresponding to susceptibility gene in the host and pathogenicity gene in the parasite respectively) related to one another reciprocally in the manner of antigen and antibody are necessary. Chapters VI and IX deal with genetics of yeasts, protozoa, bacteria and viruses respectively and contain very good surveys of our knowledge of their genetics.

In the treatment of the subject-matter of the book a Mendelian outlook is maintained. Cytochromes, suppressors and latent antigens

and their role has been considered in relation to such phenomena as adaptation, abnormal segregations, lag in manifestation of bacterial mutants, etc. Professor Catcheside has cited convincing experimental data in favour of the Selection Hypothesis while considering the nature of resistant mutations of bacteria.

J. VENKATESWARLU.